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(INCORPORATING THE METALLURGICAL ENGINEER)

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METALLURGIA

THE BRITISH JOURNAL OF METALS.

INCORPORATING "THE METALLURGICAL ENGINEER."

NOVEMBER, 1947 Vol. XXXVII No. 217

Steel Production Needs Scrap

THE iron and steel industry is contributing very successfully in supplying the needs of the various industries engaged in manufactures for domestic and export purposes. Steel production in October reached a new high record rate exceeding the production of any previous monthly period. This new record production was at an annual rate of 14,316,000 tons compared with 13,841,000 tons a year in September and 13,226,000 tons in October, 1946. Pig iron production also showed an increase to an annual rate of 8,352,000 tons compared with 7,805,000 tons in September and 8,102,000 tons a year ago.

The progress made so far is very gratifying, and there can be no doubt that the industry can meet the target of 14,000,000 tons of steel in 1948, with a substantial amount in hand, if production depends entirely on efforts made within that industry. Given relief from labour difficulties, and it is noteworthy that this industry has been singularly free from troubles that have beset other basic industries, the two main needs of the iron and steel industry are adequate supplies of fuel and of iron and steel scrap. These are vital necessities and must be available in the right quantities and qualities to maintain iron and steel plants in continuous operation. It is true, of course, that many open-hearth steel furnaces have been converted to use oil fuel, but this fuel should be regarded as supplementary since by far the major production depends upon coal as fuel; indeed, coal is the life-blood of all metallurgical industries.

Many industries have been complaining of the inferior quality of the coal available and the iron and steel industry is no exception. Apparently the increase of mechanical mining methods at the coal face has resulted in deterioration of the quality of deep-mined coal. The general supply of coal to industry has undoubtedly deteriorated both in regard to ash content and calorific value, but special problems are presented in iron and steel production and it is gratifying to be assured that both long-term and short-term remedies are being sought and no effort will be spared to ensure success. The fact that changed mining methods have altered the grading and cleaning characteristics of the coal, rendering some cleaners obsolete, is not always appreciated. However, it seems that every effort is being made by the National Coal Board to effect improvement despite the handicap of plant shortage.

On the question of quantity of coal available it would seem that labour troubles in the coal-mining industry are likely to be much less frequent and we should be able to look forward to steady progress in the coal-mining industry, which would not only enable production to to meet our own needs, but enable us to export increasing quantities and become a vital aid in closing the gap between exports and imports. Certainly production is rising, and although much leeway remains to be made up, the prospects are more encouraging than they have been for some years.

Apart from coal the importance of an adequate supply of iron and steel scrap cannot be over-emphasised. In fact, the target of 14,000,000 ingot tons of steel for 1948 can only be achieved if sufficient scrap is made available to the industry. Even before the war, home scrap supplies were about 1,000,000 tons a year below the level required. In those days the deficiency was made good from overseas sources – chiefly the United States. This is no longer possible. At the moment Germany is the only practicable source of important overseas supplies. Reserves of scrap available in various forms in Great Britain were largely exhausted during the war. The iron and steel industry's stocks of scrap are now precariously low, and it is necessary to emphasise that an increase in scrap supplies must come at once if the iron and steel production target is to be attained.

On previous occasions we have emphasised that the stock of metal in use is no less a valuable resource than unmined ore. It is frequently assumed that conservation is concerned only with the production phases of the metal industries, whether ferrous or non-ferrous, whereas the effective conservation in the utilisation phases is, at least as important. It should not be overlooked that real conservation can be achieved by promoting the constant use and re-use of that part of production which is not destroyed in service. Thus, the use of scrap metal and its use with or instead of metals produced from ores, is sound economics. This principle is recognised in all metal-producing industries. But, in the iron and steel industries, the use of scrap has become essential in certain steel manufacturing processes and supplies must become available to enable the processes to be applied.

Much has been done in engineering and other works to organise the collection of scrap and to arrange for its collection at regular intervals, but there are many works in which the collection of iron and steel scrap is not well organised; certainly there is room for much improvement. The iron and steel industry needs every ton of iron and steel for which there is no immediate use, whether in workshop or yard. Do not bury it as one transport department of a large provincial town has done in permitting tram rails, for which they have no further use, to be covered as roads are macadamised, thereby losing many tons of useful steel. Get it into the hands of a scrap merchant as soon as possible and maintain your supplies by giving instructions in every workshop to search out and discard old material. Keep in mind the needs of the iron and steel industry and its object to achieve the production target for the year 1948.

National Foundry College

THE National Foundry College has now been established and its Board of Governors nominated by the Minister of Education, representing a number of interested bodies in industry and education, under the Chairmanship of Mr. Randall G. Hosking. The College will be housed in, and work closely in conjunction with, the Wolverhampton and Staffordshire Technical College.

The Board is charged with the responsibility for providing national facilities for foundry education and research, in the form of full-time courses, vacation courses, refresher courses, and the like, and also for providing regional and local facilities for full-time, part-time day and evening courses, covering thereby the whole range of foundry education. Their first task will be the re-establishment of the full-time Diploma Course which was the main feature of the predecessor of the College, the British Foundry School, during 1935–39. This Course will normally run for an academic year of 40 weeks from September to July. It is hoped to open the first session on 5th January, 1948, to conclude in August. The Prospectus of the College and the curriculum with form of application for admission can be obtained from the Head of the National Foundry College, Technical College, Wolverhampton.

The Course will provide the highest possible training for those wishing to qualify for positions of highest responsibility in the founding industry and those who are likely to achieve such positions and wish to extend their knowledge to meet the considerable advances made during recent years. It will cover the whole of the foundry industry, ferrous and non-ferrous, including grey, white and chilled iron castings, malleable castings, steel castings, and castings in all non-ferrous metals, such as alloys of copper, tin, zinc, nickel, aluminium and magnesium. The Diploma awarded to successful students will be endorsed by the Ministry of Education.

There is no upper age limit for admission and the standard of practical experience and technical knowledge of candidates must satisfy the Board of Governors that they are in a position to profit from the instruction. A minimum of one year's practical experience in at least one branch of the industry will be required, together with Higher National Certificate, or a university degree, preferably in metallurgy or engineering, or a grade of membership obtained by examination of a professional institution in engineering, metallurgy or chemistry. It is intended to invite nationally known experts in the industry to participate in the work of the College.

The fee for the Course is £60, payable in advance. At the discretion of the Board of Governors this fee may be remitted wholly or in part for students nominated by firms belonging to trade associations or bodies contributing financially to the College. It is anticipated that many students will be nominated and maintained by their respective firms. It is hoped to provide hostel accommodation for students in due course.

Further information will be made available shortly with respect to the constitution of the Board of Governors and the bodies represented thereon. The Minister of Education, on the recommendation of the Board of Governors, has appointed Mr. J. Bamford, B.Sc., who was in charge of the British Foundry School during 1935–39, and who has since held important managerial appointments in the industry, to be Head of the National Foundry College.

Grinding and Polishing

The Romance of Carborundum Colour Filmed

GRINDING and, closely associated with it, polishing, are two methods of machining both metallic and non-metallic materials which have been used for centuries and there is a tendency to overlook the progress achieved in these operations in the past few decades. Since the earliest days grinding and polishing have been regarded as important and essential operations. During the last few decades, however, continuous and quickening progress in industrial production and improvements in working methods have brought grinding technique in an ever increasing degree, into the foreground. To-day, it can be said without exaggeration that the economical and, at the same time, qualitatively sound manufacture of many articles of consumption for daily requirements, and nearly all means of production would be absolutely inconceivable without the grinding and polishing machines now available, and without modern grinding media and grinding tools.

It needs very little imagination to realise that progress in engineering depends upon an advanced knowledge of grinding for not only is grinding essential in the production of machine parts, but also in the entire process of manufacture. But the great developments resulting from this operation are largely due to a discovery of an artificial abrasive, in 1886, by an American chemist, Dr. E. G. Acheson, which he named "carborundum." The possibilities of this new product were appreciated to some extent, but the cost of production was then so high, that for economical reasons, its application was confined to special purposes. With the development of cheaper electric power, however, and improved methods of production, great progress was made and soon carborundum was available not only in the form of powder in varying degrees of fineness, but also prepared into various shapes for mounting in machines or for handling. Production of carborundum in Trafford Park, Manchester, commenced in 1901, and so successful did this new media, carborundum become, that the name is now familiar wherever abrasives are used.

Carborundum is formed by the action of carbon on sand at high temperature in the electric furnace and is a silicate of carbon. When taken from the furnace it is crystalline, green, blue or brownish in colour, sometimes opaque, but often translucent, resisting the action of even the strongest acids, and the action of air or sulphur at high temperatures.

The romance of carborundum has lately been produced in a new colour film by the Carborundum Film Unit of which the writer was privileged to have a preview. This film traces the development of carborundum from its initial discovery through processes of conversion into usable forms to its applications in modern industry. The film occupies an hour to screen and not only is it exceedingly well produced from a photographic point of view, but as an educational film it reaches a very high level, and the producer is to be commended on the continuity of presentation of the subject which successfully holds one's interest to the end.

This film is available for showing in technical schools and colleges, societies, work's organisations, etc.; applications should be made to Mr. Harris, Carborundum Company Ltd., Trafford Park, Manchester, 17.

East Engineering Library

Die Casting Progress

I—The Industry

By Dr. A. C. Street

The production of die castings has increased enormously in recent years, principally because engineers and designers are more conscious of the great possibilities of the process and the quality of die castings has improved sufficiently to enable more ambitious die-casting projects to be undertaken. This article commences a short series in which several aspects of progress in this process will be discussed.

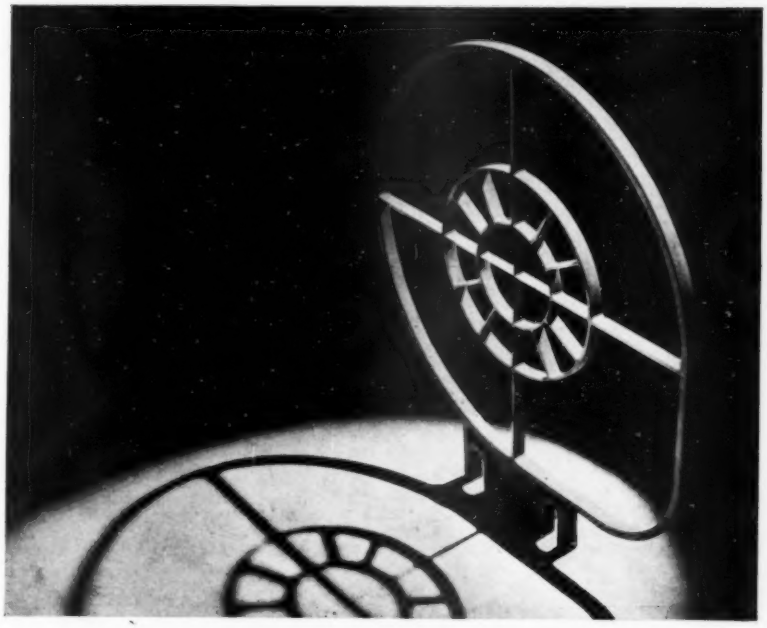


Fig. 1—Bofors gun foresight, produced as a zinc alloy pressure die casting. The centre graticule is cast into position.

ACCORDING to a recent survey,[1] 43·1% of the American metal working firms used die castings in their productions; details of future requirements of these firms are shown in Table I.

TABLE I

Per Cent.	Aluminium	Zinc	Brass*	Magnesium
Will use more	46·6	36·4	26·6	24·5
Will use less	9·3	13·3	15·2	15·0
Will use the same amount	44·1	50·3	38·2*	60·4

* There is obviously a misprint in the article. It is likely that "38·2%" should be read "58·2%."

The writer is unable to present such an accurate report on the position in this country, but from a consideration of 300 metal working firms in the City of Birmingham he deduced the following facts which may be of interest:—47% of the firms considered use, or have used, die castings during the last 15 years; 22% of such users have only become interested in die casting since 1939, while about 50% have made and maintained an increase in their usage since the same year. About 10% of the firms recorded as using die castings required them only for munitions.

To illustrate the type of firm employing die castings, 100 known users were selected at random from all parts of the country and are grouped according to their type of manufacture in Table II. It may be of interest to note that 23 of the firms considered had never used die castings prior to 1939, which compares with 22% of the cross section of metal working firms considered in Birmingham. The uses include the application of pressure die castings in zinc and aluminium alloys and also of gravity die castings in zinc, aluminium and copper alloys; moreover the quantity of die castings used by each firm varies greatly; for example one user, included under office equipment, requires only a few aluminium bronze date stamp castings per annum, whereas at the other extreme many of the manufacturers of automobile, domestic fittings, etc., use many millions of die castings each year.

In view of the enormous increase in the production of die castings during recent years, the evidence of so comparatively small an increase in users may come as a surprise. It should, however, be borne in mind that consumption per established user has risen, principally because engineers and designers are more conscious of the great possibilities of the process, and the quality of die castings has improved sufficiently to enable more ambitious die-casting projects to be undertaken.

Labour, in particular skilled tool room labour, is short in the industry and die casters have not to any large extent been able to undertake work for new customers. Moreover it is understandable that those manufacturers who employed die castings during the period of greatest development should be the first to widen their field of use.

As illustrating the extensive use to which die castings can be put in a single assembly, an article in "Die-casting" for April, 1946[2] described 45 pressure-die castings in a "Symphonola" gramophone record player—perhaps better known as a "Juke Box." Among these die-cast parts are five cams, two gears, two levers,

1 *Steel*, Vol. 115, No. 15, October, 1944, pp. 172–173.

2 *Diecasting*, Vol. 4, No. 3, April, 1946, pp. 42–46.

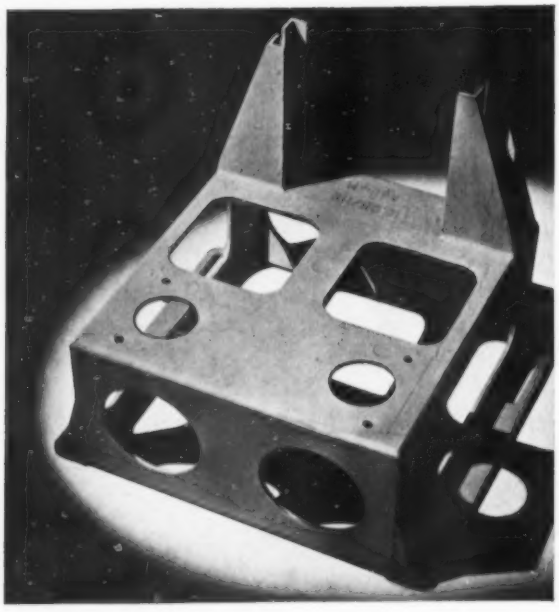


Fig. 2.—Radiolocation chassis, produced as a zinc alloy pressure die casting. It is reported that had the chassis been made in sheet metal four times as many man-hours would have been needed for production.

two flanges, one swivel, one pinion, five frames, one bearing housing and one bearing. Only four die castings are used for exclusively decorative parts. Some of the items are quite large; for example, the rear frame is 18 in. × 23 in. and it contains 46 cored holes, 20 cored slots, 15 cast bosses with cored holes and two countersunk holes.

Before the war, Britain perhaps lagged behind the U.S.A. and Germany in its use of die castings. America, for example, had in the 1930's produced the famous one-piece 28½ lb. pressure cast radiator grille for Oldsmobile, the aluminium-pressure die-cast crank case for Auburn, and the 36-lb. slot machine housing. In many ways Germany also was in advance of this country, particularly in her extensive use of magnesium alloys. Britain had a good reputation for quality, but our uses of die castings were on rather conservative lines.

The striking war-time expansion and progress of our die-casting industry took place in two stages. After Dunkirk, the realisation that man-hours must be saved at all costs despite the need for the production of countless millions of munitions in the minimum of time, led to a wholesale adoption of pressure die castings in zinc alloy for ammunitions and other service components to such effect that by 1943 the demands of the various services showed signs of being satisfied. The next, more selective, stage followed when experience had led to the appreciation that die castings could be applied to other uses including parts of aircraft, Radar and tank instruments, also gunsights and many other components which earlier might have seemed too ambitious. Figs. 1, 2 and 3 illustrate some of the war-time uses of die castings.

The major die casters in Great Britain can be grouped roughly as follows :—

1. Pressure die-casting firms catering for all trades. Some of these firms previously concentrated on zinc alloys but towards the end of the war many extended their plant to handle the pressure die casting of aluminium alloys.

2. Gravity die casters, including firms who specialise in light alloys and others who produce a limited quantity of copper alloy die castings.

3. Certain manufacturers of products such as automobile equipment, office appliances and toys, whose usage of die castings per annum is so large that they consider it economic to install their own die-casting plants. A few such factories have die-casting shops which compare favourably in size, equipment and quality of production with those of many trade die casters. Normally such concerns produce castings for their own requirements and do not compete with the trade die casters, but during the war their plants were engaged in the production of service components, particularly for fuses. While on the subject of specialised producers reference must be made to Messrs. Qualcast, Ltd., the well-known manufacturers of lawn-mowers, who have installed a now famous plant for the multiple production of iron gravity die castings.

In addition to these three main groups there are the small producers, some of whom came into existence during the war, also manufacturers of stampings and pressings who have installed small die-casting plants and numerous manufacturers of household and other fittings who have a few die-casting machines, usually for zinc alloy. Whether or not it is economic to die cast on such a small scale is controversial. One thing is certain, that many inexperienced die casters have much to answer for because of the unsoundness of the castings they produce and the use of contaminated zinc alloys which so often give rise to prejudice against die castings as a whole.

TABLE II

Type of Product	No. of Users
TRANSPORT:	
Automobile and Motor Accessories	11
Motor Cycles and Accessories	4
Bicycles and Accessories	2
Railways and Fittings	2
Marine Engine Components	3
DOMESTIC:	
Domestic Fittings (windows, doors, etc.)	10
Electric Domestic Appliances	5
Gas Domestic Appliances	3
Perambulators	3
Lawn Mowers	3
Radio	3
Gramophones	2
Bathroom Fittings	1
INDUSTRY:	
Electric Motors, Switchgear, etc.	12
Textile Machinery	5
Colliery Machinery	6
Small Tools	3
Oil Engines	2
FOOD:	
Agricultural Machinery	1
Food-handling and Bottle-washing Plant	4
MISCELLANEOUS:	
Telephones	3
Office Equipment	4
Lifts	2
Scientific Instruments	1
Weighing Appliances	1
Oil and Paint Containers	2
Petrol Pumps	2
	100

Development Associations

This is a fitting stage to pay tribute to the Development Associations which during the war years did so much to further improvements in die-casting practice and technique; they appear to be filling an equally important role in our post-war industry.

Thanks largely to the Ministry of Supply, Non-Ferrous Metals Control, the Zinc Alloy Die Casters'

Association, which includes practically all pressure die casters in zinc alloys, was formed early in 1942 and many advances made by the industry can be traced directly to the activities of this Association. The Association, which is domiciled at Oxford, has a Technical Committee of experienced die casters which has been responsible for resolving innumerable questions on die-casting design, finishing and usage. The Publications Committee of the Association have produced several booklets which have been in great demand by die casting users, and a very comprehensive treatise on the plating of zinc alloys is on the point of publication. Other books on chemical finishes and on design are being prepared.

The Light Metal Founders' Association and the Association of Bronze and Brass Founders both include a majority of sand and gravity die casters in their membership, though pressure die casters are well represented. These Associations have active Technical and other Committees.

All three Associations are now represented on the Advisory Committee (Die Casting) of the Ministry of Supply which was re-formed after the war to consider technical problems of die-casting design and application in non-ferrous alloys. The Committee still deals with questions of service components, but also is active on certain peace-time applications of die castings.

There is no doubt that these Associations have dealt satisfactorily with their individual problems, but one cannot help conjecturing whether an all-embracing Association of die casters might have been still more effective. The formation of an independent secretariat to handle the varying problems, and to reconcile the conflicting views of those handling different alloys might however, have proved difficult. In this connection it is worth noting that in the U.S.A. all the major American die casters belong to the American Die Casting Institute.

Classification of Die Casters

During the war the Ministry of Supply, Non-Ferrous Metals Control, classified the die-casting industry according to a precise standard prepared in co-operation with the Advisory Committee (Die Castings). For the purpose of classification firms were assessed under four sections in accordance with detailed systems and pre-determined scales of points awards. The four sections were as follow :—

1. Tool Room.
2. Die-casting Plant and Practice.
3. Inspection Record.
4. Production Record.

For each of the above sections, points (to a maximum of 100) were to be allotted against specific items of equipment, practice, inspection and production. The aggregate of points allotted, for the four sections, to determine the classification of the firm was according to the following grading :—

A + ...	400–356
A	355–311
A —	310–266
B + ...	265–221
B	220–176
B —	175–131

As a proviso, it was ruled that no firm who attained less than 65 points in any one section could be rated higher than B plus. Firms attaining an aggregate of 130 points or less were rated as unclassified for the production of die cast service components.

Fig. 3.—Percussion fuse, produced as a zinc alloy pressure die casting. A 60% saving in man hours was made possible by the use of die castings.

Die Casting in Other Countries

Naturally the above method of assessing the competence of individual firms may not have been universally appreciated, particularly by firms who did not agree with their own classification. Bearing in mind the difficulties encountered in classifying British die casters, it will be appreciated that a comparison of our industry with that of other countries is by no means easy.

It is difficult to give a considered opinion on the die-casting production of so vast a continent as America, but it seems that the rigid laboratory control insisted upon by British Standard Specifications in England is by no means general there; emphasis is on speed of production. All who see the attractive die-casting film sponsored by the New Jersey Zinc Co., cannot but be impressed by the ingenious devices employed for the rapid trimming of die castings in the U.S.A. The Imperial Smelting Corporation, Ltd., have copies of this film and have in the past been kind in loaning it for showing to interested parties. It seems that the United States still hold the record for speedy production in the fully automatic pressure die casting of zipper elements at a rate of approximately 20,000 shots per hour direct on to the tape. We in this country have done little on this highly specialised branch of the industry, though slider bodies are produced and marketed in great volume.

America in all probability also holds the record for size of die castings and dies. The Westfield Manufacturing Co., of River Rouge, Michigan, U.S.A., claim to have the largest die-casting machine in the world, weighing approximately 75 tons. They state that it is capable of casting 60 lb. of aluminium and up to 175 lb. of zinc alloy and can provide pressure up to 25,000 lb./sq. in. The Standard Die Cast Co., of Detroit, claim to be operating the world's largest die, weighing 28,100 lb., for producing the complete crankcase and cylinder of an air-cooled petrol engine.

Although it is likely that before the war our uses of die castings were on more conservative lines than was the case in America, it is worth mentioning that the Advisory Committee (Die Casting) mission to the U.S.A. in 1943 reported on their return that the scope of die castings in Britain was by that time considerably wider than in America. Members of the Zinc Alloy Die Casters Association recently visited Switzerland and made contact with certain die-casting firms. They found that the surface finish of pressure die castings was outstandingly good, due to excellent die-making technique and to the conscientious craftsmanship of the workers; moreover there was obviously very close co-operation between user and producer. Mostly hot-chamber type machines were employed and laboratory, including X-ray, control was little in evidence.

It is perhaps even more difficult to assess die-casting practice and quality of output in Germany during the war as many of the die-casting plants are now destroyed or not working, whilst others are in parts of Germany to which access is made difficult. Perhaps one of the most remarkable items of German equipment seen recently was a monster remote control die-casting machine for magnesium alloys.

As one who had always inclined to regard German industry as super-efficient, the writer was amazed on reading the B.I.O.S. Final Report No. 649[3] on the Piel and Adey gravity die-casting process which appears to be merely a glorification of the "rule of thumb": no designs, no temperature control, no real check on alloy composition.

General Conclusions

It is certain that we in Great Britain pay more attention to strict metallurgical control than any other country and this is naturally reflected in the quality of our die castings, particularly in zinc alloy. Our die-casting equipment and even our tool rooms compare favourably, and we are certainly not behind other countries in the soundness of our production. The surface finish of pressure die castings in this country is reckoned to be very good, but it is probable that some American and Swiss producers "have got something." The Americans most certainly excel us in trimming and finishing processes, while both the Americans and the Swiss have progressed further in cultivating that essential factor to satisfactory die-casting production—co-operation between the user and his die caster.

The writer would like to express his sincere thanks to Mr. David Kirkwood Junior, for help given in the preparation of this article. The photographs have been kindly provided by the Zinc Alloy Die Casters' Association.

3 B.I.O.S. Final Report No. 649, Item No. 21, London H.M. Stationery Office.

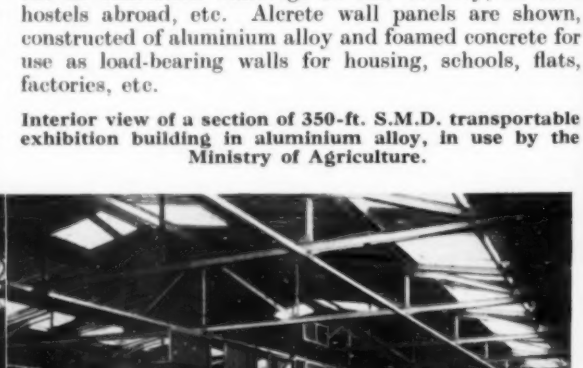
Aluminium Alloy for Roofing and Structural Purposes

CONSIDERABLE progress has been made in the application of aluminium alloy to structural work in buildings, especially transportable buildings. A notable example is a 21 ft. span roof truss of standard design exhibited by Structural and Mechanical Development Engineers Ltd., an associate of Almin Ltd., at the Building Exhibition. The weight ratio of aluminium alloy to steel is 1 : 2·6, but by the use of extrusions, whereby special sections can be economically produced for any required duty, practically the exact section modulus as required by calculation can be used. This results in an aluminium alloy roof truss only a quarter of the weight of its steel counterpart.

The S.M.D. transportable bungalow construction is also illustrated. This is a special light-weight construction combining complete demountability, high thermal insulation and the permanence of aluminium alloys. The wall panels are constructed of aluminium alloy sheet and extrusions, and weigh under 2 lbs. per sq. ft. The insulation is obtained by sandwiching glass wool blankets between a sheet of aluminium and a sheet of cardboard. The display includes a photographic illustration showing demountable storage buildings, in use as exhibition buildings in this country, as staff hostels abroad, etc. Alcrete wall panels are shown, constructed of aluminium alloy and foamed concrete for use as load-bearing walls for housing, schools, flats, factories, etc.

Section of 60-ft. heavy duty S.M.D. aluminium alloy roof truss for cinema roof.

Interior view of a section of 350-ft. S.M.D. transportable exhibition building in aluminium alloy, in use by the Ministry of Agriculture.



Consulting architects to Structural and Mechanical Development Engineers Ltd. are A. F. Hare and Partners, A.R.I.B.A.

The Place of the Metallurgist in Industry

By Sir Arthur Smout, J.P.

At one time the work of the metallurgist was confined within well defined limits, commencing where mining finished and ending where the manufacturer made use of the crude pig or ingot of metal supplied. For many years now the sphere of the metallurgist has been increasing and while the extraction of metals from their ores may rightly be termed an art, the relction of metallurgy to industry has become more nearly a science. It is the application of this science to all forms of engineering that is largely responsible for the rapid developments made in more recent years and it is appropriate that the metallurgists' position in industry was discussed by Sir Arthur Smout in an address at the Brangwyn Hall, Swansea, on November 19, to a combined meeting of technical Societies. His address is given here in a substantially abridged form.

METALLURGISTS are engaged in the practical application of scientific facts. It is all the more vital, therefore, that the right men properly trained, suitably equipped mentally, and of sterling personal character, should be attracted to this profession. Probably the majority of readers are almost solely concerned with the technical and scientific side of industrial Metallurgy and this is understandable because the financial and economic possibilities of the metal industry depend first and foremost on technical and scientific facts; therefore, it is essential that the men who direct the industry must be fully competent both by education and training to know these facts and to be able to discriminate about them. There is a wide difference between the training of the lecture room and the training of the works. The former deals with facts, static and fixed, and the latter with the employment and application of those static facts for the successful running of a "live" mobile organisation.

The first place of the metallurgist in industry, therefore, is in the classroom! There the student must be taught the facts, the basic fundamental knowledge underlying the science of metallurgy; chemistry, physics, mathematics and the natural sciences generally. He must also acquire at a later, but still early stage in his career, in detail, the mobile factors necessary to deal with a "live" organisation—these I suggest are permutations and combinations of three primary and ever-changing constituents—personnel, works practices and markets. Permutations and combinations of these are as unknown, as surprising, as never ending and as complex as those of the elements, carbon, oxygen and hydrogen. The metallurgist must learn how to accommodate these mobile factors; appreciate intelligently the full reasons for the preparation of figures, statistics and reports, indeed, be able to prepare and use such vital working tools. He must understand the constant effort being made with their aid to improve the working efficiency of the undertaking with which he is connected and its control; realise the never-ceasing modifications in the methods of industry, ever-changing by reasons of new methods, new plants, new markets, and new competitors both personal and impersonal. But all this must be based on knowledge of the facts—the science of the industry. Thus, building on a sure foundation, are linked science, works technique, economics and the art of management—the four industrial levers which change productivity from low gear to high gear.

A man who has never actually worked in a factory or works has very little idea of what is required of him and how he must apply his academic knowledge, little idea in short of how to make himself valuable to his employers, which is the sole justification for the entry of the metallurgist into industry.

It has often been levelled against British metallurgical industry in the past that the capitalist was timid in his approach and reluctant to chance his arm. While that may have been true of the past, in the main it no longer remains a fact. No trace of timidity of approach can be detected in the great enterprises as carried out at Ebbw Vale and Waunarlwydd, to say nothing of the developments now in progress in the sand dunes of the Port Talbot area. The rising figures of Britain's steel production are most encouraging, as too is the dramatic increase in the export of non-ferrous metals for 1946 by comparison with 1938. There may be, indeed there are, back waters, but the metal industry by and large is as progressive as any in the country and British metallurgy as any in the world.

My official duties during the war years, as Director-General Ammunition Production, brought me into the closest contact with all branches of the ferrous and non-ferrous metals industry and it was quite easy to spot those firms which have applied the principle of scientific organisation and absorbed the scientific approach and those which have not. The former were well managed, alive, prosperous and progressive; the latter were slothful, decadent and dying on their feet—always in trouble, ever in difficulty. Fortunately, these latter formed a small minority and I have no sense of fear that our rivals will out-distance us in the race for prosperity, provided always that the British people understand the position, realise the part they have to play and are able to follow and willing to support the work of those engaged in directing the actual field of operations. In the battle for production, which lies before us, there must be no class distinction and no engendering of class hatred, setting man against man, and I look for a lead amongst our responsible leaders of public opinion in this direction.

Science, and certainly metallurgy, is the monopoly of no country and it is always possible to place one's fingers on shining examples in all the civilised countries of the world. The beginning of the industrial era was definitely and completely a British movement and South Wales and the Midlands are so full of shining examples of worthies of this period, that there is no need to emphasise the point that the industrial revolution was born in Britain. While the industrial revolution was commenced by inventions in engineering, it was quickly followed by discoveries of first-class importance in metallurgy. One has only to mention the names of Bessemer, Siemens, Gilchrist, Lothian Bell, Muntz, Percy, Roberts Austin, Ludwig Mond, and later Rosehain

Hatfield and Brearley, to prove that in the sphere of metallurgy, Britain has always been a pioneer. Similarly in electricity and modern engineering, Britain has led the field. The same is equally true of the newer sciences of X-rays, neuclear physics and electronics.

During the past 100 years, metals have become the most important of the materials of construction, particularly in the case of " mechanisms " in the use of which variable stresses are applied to the component parts, and the coming of the metallurgist can be said to date from that time. As mechanisms have become more and more complicated, the importance of the metallurgist has increased steadily until we arrive at the position of to-day when metallurgy is the key-stone of engineering progress.

One of the great disadvantages metallurgical industry has suffered in the past is the fact that the so-called academic metallurgist and the works man have, as it were, existed in mutually hostile camps. The one alleged the practical man knew nothing, and the other that the academically trained man, might be all right in the laboratory, but he was of little use in putting his ideas and theories into practice.

This drifting apart of two partners was not entirely the fault of industry, for the academic metallurgist has, in the past, often ignored industry. This may have been due to the complexity of modern industry and to the apparent cumbersome nature of so many factors, but we have long since got beyond this stage. There is however, still room for an even closer liaison between the academic and the practical side of the industry.

We might consider the desirability of setting up an advisory body, comprising both academic and industrial metallurgists, to consider together the problems arising in the metallurgical field. Some of us are so close to our troubles and so engrossed with day-to-day affairs that we are not doing the forward thinking so essential to progress. This suggestion may provide a solution of this problem of " forward thinking."

I fully subscribe to the late Mr. Gluckstein's edict that " the successful business man of the future will have to be a scientist or at least to have some scientific training." However, I am not for one moment suggesting that a Board of Directors should consist entirely of highly scientific people ; there are other branches of special knowledge besides science necessary to run a business. A knowledge of finance, of business technique, of production methods, a capacity for organisation, or for sales, or the simple, though all-important and yet often ignored qualities of character and personal integrity, can and will long continue to lead a man to the topmost rungs of the ladder and yet, added to this, particularly in ferrous and non-ferrous metals industry, some knowledge of the science and practice of metallurgy is essential, excepting perhaps for the gentlemen who are responsible for the purely figure side of our business

Function and Scope of the Metallurgist

It will be appreciated by all who are conversant with industrial organisation that it is not possible to draw sharp lines of demarcation between the various branches of work in which the metallurgist in industry may be called upon to exercise his scientific knowledge ; nevertheless, it is convenient to divide the function and scope of the metallurgist into sections, provided it is clearly and freely understood that these may overlap or dovetail into each other and that many observations made in regard to one may be applied almost equally to others. Two branches, however, stand out as being fairly sharply distinct : manufacture and production, and control, research and development. The highly important commercial side of the industry, in which the trained metallurgist can play and is indeed playing an ever-increasing part, will fall under the main head of manufacturing and production.

Manufacture and Production.—The metallurgical industry is now becoming so highly technical and scientific that to have adequate metallurgical knowledge behind *all* its operations has become a necessity, if commercial success is to be attained and, therefore, it is no uncommon thing to find and indeed, it is highly desirable to have, trained metallurgists, in all departments, with perhaps the one important exception of accounts, although even here there is an important niche for the technician on the costs branch of the accounts department if costing is to be done intelligently.

If I were asked to sum up in a couple of words the most conspicuous difference between the academic and the research laboratory on the one hand, and the manufacturing and production side of the metallurgical industry on the other, I should without hesitation say " *time and cost*," and it is here perhaps, that the works new entrant encounters the greatest difficulties and finds the conditions most strange.

It is for this very reason that I have always urged young men, if they have any ambitions on the factory side, not to leave their choice too late, for the entry must be gradual and relatively early, so that the wide difference between the training of the lecture room and the training of the works may be successfully bridged. Much of this works knowledge must be self-acquired and ferreted out personally, for though the new entrant will take orders from his " chief " and receive from him general guidance and sound advice, and be able to learn much from his colleagues and especially, if he has the right approach, from the more skilled operatives, yet he must not expect to be " spoon fed." Our works are not a teaching institution. I am not averse to Staff Courses by any means, but they can be overdone. My advice to the young man is to get out and about and to " learn while you earn." It is a hard school, but a very sound one.

The manufacturing processes in the metal industries are complex and diverse in character and permit of endless combinations and permutations and the various stages of a process of manufacture have to be cunningly dovetailed in with the working hours of the factory, with the plant available, and with the labour force at one's disposal. The mistake of a careless assistant, or a disinterested operative generally results in the complete scrapping of all operations up to that stage and the re-working of a batch of metal with increased costs, which is bad enough in itself, but it also entails a loss of time, which is frequently a far more serious matter. The problem of production in any industry is to obtain the greatest possible yield of product of the highest possible quality, in the shortest possible time and at the lowest possible cost and it is here where the metallurgist can make his greatest contribution, and where his scientific training and knowledge will serve him in greatest stead.

Metallurgists, therefore, should be employed in production and manufacture—to control all works operations dependent on metallurgical science and

technique, whether they be refining, casting, rolling, extrusion, heat treatment or the many other operations involved.

If the metallurgist has been well and systematically trained, on a broad basis, in the theory and practice of his science generally, he will have developed an instinct for the "law and order" of things which will fit him for control in works operations where law and order are above all essential to successful production. Metallurgists should be trained observers, for trained observation is more than half way towards winning the battle of production. Operations must be conducted systematically and where "law and order" is, there should be the trained metallurgist. He need not of necessity in his early days know all the details, or be the most skilful operative in the shop, the main point is that principles must be understood, before it is possible to understand the processes and, certainly, before it is possible to modify, tune up and improve such processes, which objective should be the metallurgist's prime consideration when entering the production side.

If he understands the basic principles, in course of time and, indeed, quite quickly, he will become better acquainted with the processes involved and learn to appreciate the influence of scientific methods on large-scale operations. He learns this part of his business much as his counter-part, the works engineer, does, by practical experience. He should therefore, not be too fastidious about taking off his coat and getting down to things, with dirty hands and a grimy face. He may in an emergency have to handle materials and plant himself; in fact, do anything that the workmen under him are required to do.

If the young metallurgist entering industry is not, as occasion demands, prepared to tackle the hard work of the factory and to live alongside his men, he would be well advised to leave the manufacturing side of the business alone and confine himself to some other branch of the profession. Certainly he will have no just cause for grousing when in middle life he finds the "plums" of the profession have gone to others who in their earlier days seized their opportunities and were not reluctant, on the contrary were keen, to get down to things.

The aspirant for a senior managerial position in the metallurgical industry is in a much stronger position, if he can regard, with interest and enthusiasm, consideration of the economic factors, labour and social conditions which are so much part and parcel of the complete scheme of production and manufacture. There is a big demand for competent metallurgists who are men of business and to whom the great metallurgical concerns can look to enable them to maintain and increase their position in industry. Men of the right stamp, men of practical ability, imagination, initiative, energy, who are capable of handling their fellow men and can grasp the full significance of large-scale operations are always in demand and when they have become established can usually be certain of coming out somewhere near the top.

There is need of the metallurgist who can administer; but as the number of men who can administer successfully is limited. It is hopeless to put the scientist in an administrative job unless he has much more than his scientific knowledge; he must have the power to think clearly and, above all, possess personality. I realise that the term "personality" is not concrete; it indicates something nebular, but it is, nevertheless, a very definite characteristic, and one which is an absolute essential to the successful administrator. Thus, the application of the science of metallurgy to industry and its many complex problems become much more interesting and perhaps even more important and certainly more remunerative to the individual concerned, than purely the work of the academic metallurgist or his counterpart in the work's research laboratory.

The metallurgist who has so narrow a conception of his science as to feel that these wider considerations detract from the value and interest of metallurgy as a science is not likely to be of much, if any value, to industry. On the other hand, if a man by temperament and training is interested in these wider factors, and regards them as additional incentives to the solution of problems, which as a whole are more complicated than those of research, he will be more and more in demand and with increasing experience, will find himself drawn into the administration and direction of the industry he serves.

Many metallurgists in the course of a few years' experience, have fully shown their ability to tackle works problems as they arise however diverse they be, and have therefore, become fully incorporated in the firms to which they are attached. Such men have gifts of personality and leadership, they are essentially practical, possessing that unerring facility of getting things done, not necessarily in the best way, or the most expedient or the quickest, but the most reasonable under the circumstances of the hour, while they are conscious of their limitations and know when to call in expert advice and assistance from their more academic colleagues.

Control, Research and Development.— It is an excellent practice to place the young metallurgist in the "Lab." especially in the larger works, for here he is not only in touch with everything that goes on technically, but it gives him time to acquire the all-essential factory outlook and provides a cushion between the cloistered life of his University and the rough and tumble of production and the hard knocks of industry. It is customary to draw largely from the laboratory to staff the works production side. Such transference is generally welcomed for it is usually considered a promotion to be selected from the junior ranks of the research department for a position in the works and men seldom want to return to the laboratory if they make good on the plant. Responsibilities grow quickly with success, administrative work accumulates and gradually they are weaned, not without regret, from a scientific career as such, but always retaining that scientific outlook, that "law and order" approach to production problems, which means so much towards the successful running of a factory and the carrying out of a series of scientific processes we call "production."

The more or less routine work of control in a metallurgical works is a matter of considerable moment and forms an important section of the metallurgist's industrial field. The duty of this section is to keep a watchful eye on everything that is going on and while it has to *some* extent to justify its existence by finding fault, its motto must be "Prevention is better than cure" never "let well alone"—I know of no more certain road to ruin and could cite more than one instance of a one-time successful firm "letting well alone" only to wake up too late to find its business gone to the more

enterprising competitor gifted with a spirit of restlessness and "divine discontent."

It is no use waiting for problems to be put before you. You must search for them yourself, for in many cases those who are working a process in a non-scientific way fail to appreciate where problems are to be found. They are hedged about by the limitations of their knowledge, they fail to observe correctly, they do not appreciate the importance of "law and order"—all of which shortcomings the metallurgist, with his wider training and full appreciation of the scientific principles underlying the process, should be able to amplify.

Of recent years this work of control has spread to the users of metals and there is an important piece of work and an extending field of usefulness for the metallurgist in what has been termed the "user field."

Investigation of failures, disappointments and of general conditions of working on the plant should lead to research and research to development of new metals and alloys, new processes, improved methods, and inventions. These are concerned with improvements in existing processes, or their substitution by more efficient ones; improvements in quality and reduction of scrap, detecting the causes of faults and failures; the working out of new methods which will tend to economise development or the manufacture of new products. Reduction of working costs.

In a works of any standing, however small or specialised, such a programme is sufficiently wide in its character to offer an attractive field to a number of trained investigators. This work calls for close application and a certain amount of "detachment" and as it may cause such a serious hindrance to the routine work of production as to necessitate its removal from the rush and hurry of business, if it is to receive, as it must, the necessary and thorough attention. But here again, the investigator must not shut himself off from the works, much time must be spent in the factory itself, only resorting to the laboratory when some work requires systematic investigation.

The industrial metallurgist, engaged on research, who remains within the locked doors of his laboratory will be hopelessly at sea and left behind in the race for progress. It is impossible to say how far the work should go in the laboratory itself and when it must be transferred to the works, this largely depends on the works, the worker and the problem, but of one thing I am certain and that is that the closest possible contact with the works should be established early and maintained right through.

Metallurgists continue to increase numerically and yet the profession is not overcrowded, indeed, recent impartial investigations have shown that we need four times the annual intake of trained men in comparison with that of 1925-1935. This is due to the much extended employment of adequately trained men in industry and in industrial research organisations. Increased opportunities have also been due, particularly in more recent years, to the more frequent promotion of metallurgists qualified by knowledge, personality, gifts of leadership and capacity, to posts of management and responsibility in industry and commerce.

The amazing developments that have been made in the extraction of metals and in their manufacture can be seen in true perspective only when compared with the conditions of early times. A review of the history of metals shows what industry owes to the trained metallurgist's ascendancy in the works and to the application of scientific principles. To-day, metallurgists are occupying positions of increasing importance; their influence on the national life is growing daily.

Dorman Longs' Development Scheme

A DORMAN LONG project for the installation at their Cleveland Works of new blast-furnace plant at an estimated cost of £4,640,782 is under consideration by the Iron and Steel Board. The scheme provides for two new blast furnaces, which will be the largest in this country, together with the necessary extension of gas cleaning and distribution plant, new railways and bridges.

The Company's new open-hearth steelworks being built on the Lackenby site, in association with the beam mill, will be linked by private railway line with Cleveland and Redcar Works. Cleveland, Lackenby and Redcar Works will have a combined maximum iron demand of approximately 22,000 tons per week. This is much greater than at any other British works. Provision is made in the scheme for feeding molten iron to the Lackenby steelworks and replacing much of the old, and to-day uneconomic, blast-furnace capacity at Cleveland Works.

The site selected for the new blast furnaces extends over 48 acres, and will permit of the installation of the five or six blast furnaces that may be required eventually if the Lackenby site is developed to its maximum steel-making and rolling capacity. The new furnaces will be situated close enough to the central ore unloading and preparation plant now under construction, and the existing large coke-oven batteries, for the raw materials to be delivered to the blast furnaces by belt conveyors. To meet the need for additional large capacity blowers the new boiler house plant will be almost doubled and all blast-furnace gas will be effectively used at the Cleveland and Lackenby works. Hot metal and slag ladles of 75 tons capacity requiring new large locomotives and rolling stock will be used to transport the molten iron between the blast furnaces and Lackenby (three miles), and when necessary, to Redcar (four and a half miles). The new furnaces will have a hearth diameter of approximately 27 ft. and an output of 7,250/7,500 tons of basic iron per week per furnace.

It is anticipated that the two new blast furnaces with the consequential extensive redevelopment of essential services, can be completed within three years. The possibility of construction of a third blast furnace being undertaken before the two now approved are completed, is envisaged by the Company. The project is directly in line with the National and North East Coast development plans for the iron and steel industry.

Price of Aluminium

THE Minister of Supply announces that as from November 6th, 1947, the price of virgin aluminium in notch-bar form will be increased from £80 to £82 10s. per long ton delivered into consumers' works. The increase in price reflects the additional cost of metal in notch-bar form.

The British Iron and Steel Research Association

Official Opening of Physics Laboratories in Battersea

The new laboratories of the Physics Department of the British Iron and Steel Research Association, which is organised in accordance with a plan approved by the governing council of the Association, have been officially opened. The Rt. Hon. Lord Rayleigh, F.R.S., performed the opening ceremony, in which he was supported by Sir Edward Appleton, F.R.S. and some 70 well-known scientists and industrialists. Brief reference is made to the opening ceremony and to the functions of the department.

THE new laboratories for the Physics Department of the above Association have been designed, equipped and staffed to meet a threefold need: (1) To keep in touch with the advances of physical science with a view to possible application in the iron and steel industry; (2) to carry out research into the more fundamental physical problems connected with the work of the Association; and (3) to carry out on behalf of the divisions, research and development in fields of physics which are common to more than one division.

In order to carry out these functions the Department is divided into five sections corresponding to five main lines of connection between physics and steelmaking on which the arrangement of the laboratories is also based. These sections are general physics; instruments; heat and thermodynamics; aerodynamics; and mathematics. The programmes of these sections are based on two guiding principles: (1) Experimental work should be backed up by theory wherever possible in order to avoid laborious testing of every combination of conditions; and (2) the use of similarity theory can greatly enhance the value of a research laboratory by enabling it to test on a fundamental scale the key laws underlying the complex industrial processes.

Opening Speakers

In his opening speech Lord Rayleigh did not claim any specialised knowledge of iron and steel research, rather did he regard himself as a sympathetic onlooker. He referred to the early days of smelting iron ore with charcoal and thought the pioneers must have been puzzled by the varying of the iron they obtained. It must have needed great scientific insight to discover that all depended on how much carbon was absorbed from the fire. There was not much control by pyrometers and the like in those days and there was plenty of room for luck in the process of absorbing carbon and of hardening and tempering, and if the result happened to be unusually successful it was attributed to some occult cause. It is interesting to notice how strong is the natural human tendency to resort to explanation of this kind. Under the influence of science we are gradually unlearning it.

Continuing he referred to the development of satisfactory pyrometers which has put many of the processes in steel manufacture and use on a metrical basis, and mentioned the platinum thermometer developed by H. L. Callendar as perhaps the first step in accurate pyrometry. He referred also to the late Professor Max Planck, the famous discoverer of the law of temperature radiation on which the measurement of high temperature depends.

The addition of carbon to iron, making it into steel, is far more important than anything else we can add: and indeed the practice of adding other elements has developed within the recollection of many of us. Perhaps future progress may never show any metallurgical discovery as important as this. We now add nickel to give tensile strength, chromium to give resistance to corrosion, and both of them together with molybdenum to give strength and resistance to corrosion at the temperatures used in the gas turbine.

Sir Charles Parsons fully appreciated the advantage of the gas turbine. As was known from the time of Kelvin and Clausius, the essential point is in the use of high temperature, which defines the attainable limit of mechanical efficiency. The whole problem depended on getting a material for the rotor and blades which would stand up to a high temperature. Since that time great improvements in heat-resisting steels and other special alloys have made it possible.

Concluding, Lord Rayleigh referred to the organisation of research as a very different thing to what it was, even if it can be said that it had any organisation at all. Now it was a career. He was not inclined to believe that many Newtons, Faradays and Rutherfords exist undiscovered to-day, but it was certain that with proper opportunity and organisation, minds of by no means so rare a type could and do make great contributions to the progress of science and technology. He regarded it as a pleasure to take part in the inauguration of the Physics Laboratories of the British Iron and Steel Research Association, and had pleasure in declaring them open.

Following Lord Rayleigh, on behalf of the Department of Scientific and Industrial Research, Sir Edward Appleton, F.R.S. welcomed the opportunity of offering on behalf of D.S.I.R., warm congratulations on the extension of the Research Association's activities. He remembered the birth of this thriving youngster, but, although the Research Association in itself is youthful, the research spirit has for many years been alive in the iron and steel industry, and it must be gratifying to the pioneers in that connection to see the steady development of the central research organisation under the vigorous leadership of the Council and the Director, Sir Charles Goodeve.

He felt that he must mention the name of one who had continuously borne witness to his firm belief that scientific research is the price of progress in industry; he referred to Sir William Larke. Zealously and selflessly over a long period he had served the cause of industrial

research, not only in the iron and steel industry, but in the whole manufacturing activities of this country.

Continuing, Sir Edward said, "To-day our thoughts go naturally to the men and women who are going to work in this new laboratory. In that little-known epic of the steel craftsman, Harry Brearley's "Earning a Living," he somewhere says: 'The pleasures of occupation are twofold—having a chosen aim and a delight in the process of reaching it.' We hope—indeed we know—that your staff, while faithfully serving your industry, are going to enjoy the pleasure and the challenge of the chase. And on behalf of your guests may I wish that their activities may be exciting as well as fruitful and productive."

Mr. D. A. Oliver, Research Director of the B.S.A. group, speaking on behalf of the B.I.S.R.A. Council, said this was a red-letter day in the history of B.I.S.R.A. and the steel industry. B.I.S.R.A. was now functioning as a central research organisation for the individual research laboratories of the industry. The stage had been reached where throughout the industry many investigations were getting outside the scope of individual laboratories. This was where the Research Association was able to fill in the background to enable further individual advances to be made. Mr. Oliver instanced the aerodynamic work being carried out at the laboratories on a scale not approached by any individual works. The benefits of these investigations would accrue to the whole industry and were already giving rise to trials and experiments of great interest. This laboratory was extremely well equipped in that the marriage of theory and practice was solemnised by the good offices of the High Frequency Induction Melting Furnace, so that the theoretical tendency to become too theoretical was able to check the practical tendency to become too empirical. Throughout this organisation B.I.S.R.A. was fortunately able to work in the closest contact with industry, and he was glad to say that arrangements were being made for interchange of scientific staff between the Physics Laboratories and Works Laboratories. On behalf of B.I.S.R.A. Council he was proud to participate in this inaugural ceremony.

The Laboratories

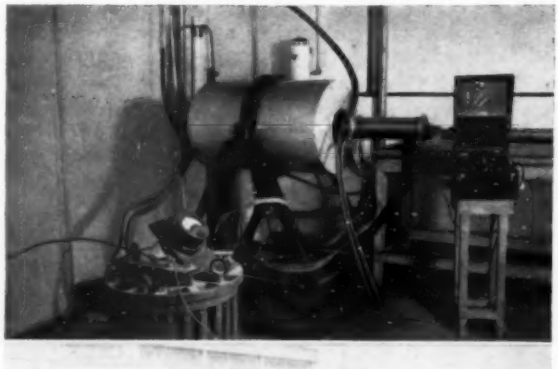
Each of the sections of the Department is allotted one main laboratory and two or three small offices, while in addition the Heat Section has a high-temperature furnace room for radiation and pyrometric experiments, and the General Physics Section has an X-ray laboratory and dark rooms. A laboratory workshop is regarded as one of the most essential units. There is also provision for a laboratory for the Association's Chemistry Department and one for the Steelmaking Division.

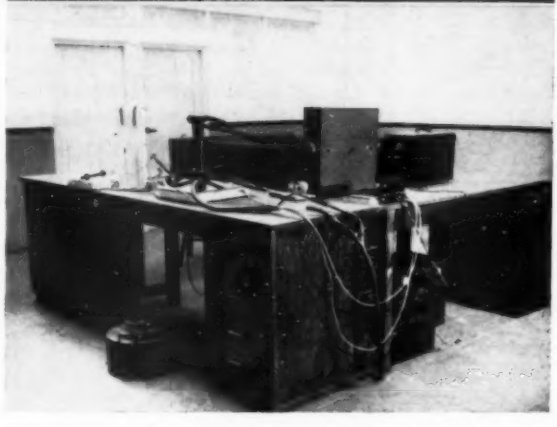
The General Physics Section is broadly concerned with the study of the physical properties of steel and the materials used in steelmaking, and of the inter-relations between these properties. In order to avoid overlapping existing programmes, this broad field has been narrowed by the choice of bulk rather than surface properties and of properties of iron and steel above 1,200° C. The physical properties of steels above 1,200° C. are of great importance in the making of steel and are accordingly especially suitable for extensive study. In addition to its usefulness for improving existing methods of casting steel, study of its high-temperature properties is likely to give results of great value in the development of a continuous casting process. Work with these ends in view is being undertaken.

No method has yet been worked out which will predict failure from fatigue. It is proposed to examine the relation of various physical properties to the state of fatigue; for example—thermo-electric power against untreated material.

In view of the interesting results obtained by a study of the Bessemer furnace flame by spectrographic methods a thorough investigation will be made of the flames occurring in all steelmaking furnaces and blast furnaces. Apart from the value of such investigation in studying the fundamental process of combustion in furnaces, the information so obtained may quite well lead to sound and rapid methods for the control of quality.

Black body furnace with 3-in. aperture for calibrating pyrometers up to 1,700° C.





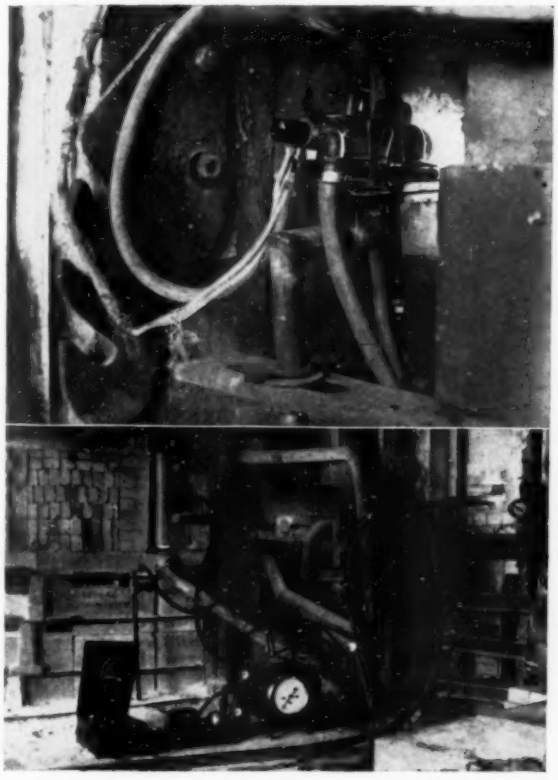
Measurement of heat transfer with time of cooling ingot. Sensible heat meter, showing potentiometer, pump and gas meter.

Other lines of investigation under examination include the use of X-ray diffraction methods for studying the physics of sintering as applied to blast-furnace sinters, the use of dynamic atomic models to bridge the gap between wave mechanical theory and engineering properties of metals, the X-ray study of the freezing of liquid steel, and the relation between internal strain and magnetic and electrical properties.

Major items of equipment are a Metrovick X-ray diffraction set and a Philips 50 Kilowatt output high frequency induction furnace, which is shared with the Chemistry Department.

Instruments Section.—The main function of this Section is to encourage and assist the application of instruments in the iron and steel industry for investigation and control of the various processes involved. Its activities may be classified under two headings: (*a*) Research on the development and application of instruments and instrument techniques; and (*b*) co-operation with instrument manufacturers and other user industries to assist in improving the supply and application of existing instruments.

Front wall pyrometer mounted between door-jambs of open-hearth furnace.



Sensible heat meter, showing potentiometer, pump and gas meter.

Several lines of research are nearing completion. A wire tension meter has been developed for continuous measurement of tension in wire passing through a wire-drawing machine. The principle applied is that the frequency of free oscillation of a wire whose length is defined and mass per unit length known is a direct function of its tension. The wire is electrically maintained in vibration at its fundamental frequency by a similar technique to that adopted in valve-maintained tuning forks, and the frequency of vibration is measured by an electronic frequency meter. Another project of general interest is the development of an electrical pressure meter for measurement and remote indication of the differential pressure existing at the roof of an open-hearth furnace. A null balance technique of measurement is adopted in which calibration of the instrument is relatively insensitive to temperature coefficients and other characteristics of the instrument subject to variation through the course of time.

An experimental pyrometer using a lead sulphide photo-sensitive semi-conductor cell as the detector has been constructed. The spectral response of these cells, with the peak in the range of 1–3 microns, suggests their application to low-temperature radiation measurements both from the point of view of sensitivity and suitability of the effective wavelength. A two-colour radiation pyrometer has been developed in collaboration with H. Tinsley and Co., Ltd. This instrument relies on a measurement of the ratio of the radiation energies falling into two narrow wavebands selected by optical filters for determination of the source temperature.

Another project being dealt with by the section, in conjunction with the Steel Castings Division, is an investigation into the control of side blown converter furnaces from observation of their flame spectra. A photo-electric indicator unit has been developed to give selective response to spectral lines appearing in the region 4,000° A., following the indication from earlier investigations that the appearance of a manganese resonance line at 4,033° A. might be capable of correlation with the progress of the blow.

The section's second function may be summarised under three heads: (1) Progress has been made in standardisation and other matters designed to improve the supply and quality of instruments for use in the iron and steel industry in collaboration with other industrial users of instruments and with the instrument industry; (2) it is now agreed that B.I.S.R.A. shall deal comprehensively with the problems of instrumentation in the iron and steel industry; (3) the Instruments Sections functions also for the various divisions, etc., of B.I.S.R.A. as a Central Advisory Service on laboratory and industrial instruments.

The equipment of the Instruments Section includes a number of standard laboratory instruments such as precision potentiometers, a decade oscillator, valve voltmeter, cathode ray oscilloscopes and a selection of ammeters and voltmeters, including current recorders.

Heat and Thermodynamics Section.—This section has the task of investigating the processes of heat flow and heat liberation, radiation from solids and flames, calorimetry and temperature-measurement being of special importance. These investigations may be divided into three main groups of projects: the thermal properties of flames, radiation pyrometers, and surface temperature measurement.

On the thermal properties of flames two projects are in hand: the sensible heat meter, an instrument designed to measure directly that property of furnace gases which is needed for a heat balance—namely, the heat content per unit volume, particularly where gas temperatures are too high to be measured directly; and the front wall pyrometer, an instrument to indicate to the operator the rate at which an open-hearth steel-melting furnace is working by measuring the total radiation from the flame, upon which the working rate depends. A mirror-type total radiation pyrometer of standard design but reduced size can be installed permanently in a protected position in such a way that the cone of vision is completely filled by the flame backed by hot brickwork.

At the request of the Pyrometry Committee of the Steelmaking Division, an investigation is being carried out into the properties of available radiation pyrometers under laboratory conditions. The factors to be

investigated will include constancy of calibration, sensitivity, effect of ambient temperature, aperture and distance sensitivity, effect of change in source emissivity and response times.

A surface temperature measurement project is also being carried out for the Pyrometry Committee. Measurement of the surface temperature of metals in the soaking pit and forging furnaces is very important since the temperature at any point inside can be calculated from this figure together with the physical properties of the steel.

Side blown converter model in operation.

View of part of general physics laboratory.

Other projects under consideration include the study of the thermal conditions in the hearth of the blast furnace and the attempt to obtain quantitative data on luminous radiation.

Aerodynamics Section.—The function of this section is to investigate the fundamental characteristics of the flow of gases in furnace systems and the flow of those liquids and granulated solids which are of importance in steelmaking, especially of liquid steels and slags. The first main problem under investigation is that of the flow of air and gas in an open-hearth furnace, since it has been shown that the mixing conditions have a very marked effect on thermal efficiency. The frictional pressure losses which occur in the gas uptake and gas port have been measured by means of $\frac{1}{12}$ scale models. This work will now be extended to investigating the influence of furnace design upon the mixing of gas and air within the furnace chamber. Two methods of measuring the mixing are being examined. In the first a $\frac{1}{12}$ scale model furnace with transparent sides is being used, and the air flowing through the gas port will be made visible by smoke coloration.

In order to study the churning action of the air blast on the liquid steel a $\frac{1}{8}$ scale model has been constructed in transparent plastic material. The physical forces of gravity and viscosity are both concerned and a part of the experimental work will be aimed at determining their relative importance by using water and mercury as fluids. A second converter of $\frac{1}{5}$ full-scale is being built in order to enable the relative importance of viscous and gravitational forces to be estimated.

Other projects under consideration are: (1) The splashing of liquid steel in moulds, and its flow along launders and out of ladle orifices; (2) gas flow in blast-furnace gas cleaning plant; (3) cold air and gas flow in a newly-built open-hearth furnace; and (4) determination of the characteristics of valves for use in automatic control systems.

Mathematics Section.—It is a central part of the policy of the departments of B.I.S.R.A. that all experimental investigations should be carried out in conjunction with a theoretical examination of the problem. The aim of Mathematics Section is to provide the theoretical examination in as fruitful a form as possible. Eight investigations of this type are already in hand: (1) Continuous casting calculations; (2) blast-furnace theory; (3) All-basic open-hearth roof; (4) immersion pyrometer; (5) furnace probes; (6) Bessemer converters; (7) technical data on fuel; and (8) diffusion analyser. In addition this section has carried out various minor projects for different divisions in the Association, including statistical work and calculations on a new method of computing roll forces for the Mechanical Working Division.

Other Sections.—The Chemistry Department's laboratory at Battersea will be devoted to investigations into the fundamental thermodynamic and kinetic aspects of the behaviour of iron and other elements during the processes of iron and steelmaking. The essential close co-operation between the Chemistry and Physics Departments will be ensured by their working in the same building.

The Steelmaking Division will carry out at Battersea work connected with instruments and process chemistry. Its accommodation at Battersea is temporary, pending the arrangement of more extensive facilities possibly nearer a steelmaking centre.

Metallurgy and Atomic Energy

By C. Hubert Plant, F.I.M.

There can be no doubt that the advent of atomic energy will become a landmark from which to survey future developments in all fields; it is an event of tremendous implications and few will yet be able to assess the effect of its impact on human affairs and upon industry. Various aspects of the subject from a metallurgical point of view will be discussed by the author in a short series of articles. In the present article, the first of the series, attention is directed to the general underlying principles of atomic structure.

THE most fundamental phenomenon of the universe is energy, and the question naturally arises, what is meant by the word "energy?" It was first used by Dr. Thomas Young who, in 1801, became Professor of Natural Philosophy at The Royal Institution and he used it to describe the possibility for action or capability for work and subsequently it has been used in many ways. There is energy of position or potential energy: there is energy of motion or kinetic energy, and in several other ways the word is used to describe forces acting or work being done.

To-day, however, the word implies an idea much more profound and important than any which are implied by the uses mentioned. In modern scientific thinking, this word "energy" is used to describe the something or the power which is really the underlying and essential fact of all facts and of all phenomena, except the facts and phenomena of mind. In short, all matter, everything with which we have to deal in everyday life, and every form of matter which occurs throughout the universe, is a manifestation of this mysterious power to which is given the name energy.

What is this power? We do not know, and it is doubtful if this knowledge will ever be gained. The most that is known is that it manifests itself to our powers of scientific perception as various forms of electric charges, which, when arrayed in orderly form and in vast numbers, manifest themselves to our senses as matter. Matter, thus composed, is held together by forces which appear enormous to minds which have only recently been able to realise their magnitude and the manifestation of these forces we term atomic energy.

It was in the year 1804 that John Dalton propounded his atomic theory. Briefly, this is what he stated: All matter is made up of small particles which are indivisible and which he termed atoms. These atoms are indestructible and those appertaining to any particular element are all alike and are different from the atoms of all other elements. Compound atoms are formed by the union of elementary atoms and this combination takes place between small whole numbers of atoms. It is surprising how closely related these statements are to the views of Leucippus and Democritus in the 6th and 5th centuries B.C. Dalton also saw that there must be some means of comparing one element with another by means of its weight. The element he took for comparison was the lightest element known—namely, hydrogen, and he made attempts to give comparisons of other elements considering hydrogen to be 1. It happened that the atomic weights of many other elements to this standard proved to be very nearly whole numbers. This fact caused Prout, one of the pioneers of physiological chemistry to put forward the hypothesis that the atomic weights of all elements are multiples of those of hydrogen, in which case the atomic weights of all elements should be whole numbers. This, however, was proved not to be the case, consequently Prout's hypothesis was considered incorrect. As will be seen later, he was far nearer the actual truth than he knew. It is now the general practice to take oxygen as the standard with an atomic weight of 16, but by this standard with modern means at our disposal the atomic weight of hydrogen is 1·008. This is an important fact and again the reason why will be made obvious later.

Dalton's atomic theory was accepted throughout the 19th century. No one apparently doubted that the smallest particle of any element was the atom, and that it was indestructible as well as indivisible. On the other hand, no effort appears to have been made to ascertain its shape, size or other distinguishing features. It was presumably a spherical, bullet-like particle, so small as to be invisible under all circumstances, and it was not until 1897 that Sir J. J. Thomson, of the Cavendish Laboratory, Cambridge, startled the scientific world by declaring that the atom "is not the ultimate limit to the subdivision of matter"; one of the most profound statements ever made by a scientist. What was the starting point of research which led to Thomson's discovery can never be definitely settled, but there is no doubt that Faraday's laws of electrolysis, put forward in 1834, had a large bearing on the subject, for on April 5th, 1881, Helmholtz in his famous Faraday Lecture said—"Now the most startling result of Faraday's laws is perhaps this. If we accept the hypothesis that the elementary substances are composed of atoms, we cannot avoid concluding that electricity also, positive as well as negative, is divided into definite elementary portions which behave like atoms of electricity," and ten years later G. Johnstone Stoney gave the name "electron" to this "definite elementary portion." But there was another and perhaps equally important factor. Since as far back as the year 1705 physicists had obtained curious phenomena if they attempted to pass an electric current through gases contained in tubes which had been evacuated as much as was then humanly possible.

These experiments came to a culmination by ten year's work on the part of Sir William Crookes, using what were then termed "Crookes tubes." He determined that something must be passing through these tubes in the shape of an unknown radiation which he termed "cathode rays" and which he thought was a fourth state of matter. Crookes himself proceeded no further, and it was left to other physicists to prove that the cathode rays were deflected by a magnet in just the same manner as would be negatively electrified particles

and in fact behaved in every particular just as such particles would do. Hertz now complicated matters by showing that these rays would penetrate thin sheets of metal and were then still able to cause luminosity.

It was at this stage that Sir J. J. Thomson set himself to prove conclusively what the constitution of cathode rays was. Assuming that they were some form of particles he determined their velocity and was able to announce that this varied with the pressure of the gas in the tube, also that it was greater than the speed of any known moving body. His next step was to find the ratio of the charge to the mass. He found, however, that the rays which produced this ratio were always the same and no difference could be found if the pressure of the gas was altered or if the shapes of the tubes were altered. What was more important, it still remained the same when the types of electrodes in the tubes and the kind of gas used was varied in many ways. Finally, he was able to prove that the charge on the cathode rays was the same as that on the hydrogen ion isolated by the electrolysis of water. They were undoubtedly charged particles or corpuscles, as he termed them, but still he was not satisfied.

Further experiments proved to him that these particles were liberated when metals were raised to a red heat, when metals and other bodies were exposed to light and even by some substances when they were cold. And always the mathematical results were the same. The matter was proved, and he was able to make his profound statement which ended with these words, "The corpuscle appears to form a part of all kinds of matter under the most diverse conditions: it seems natural, therefore, to regard it as one of the bricks of which atoms are built up."

The next question which arose was—Is there any evidence of anything which bears a positive charge? It was impossible to think of nothing but negative electricity, otherwise there could be no thought of stability in anything. There was evidence that something approaching positive rays was a fact and Thomson proceeded to expand the experiments and calculations in this direction. He met with success and was able to pronounce that the mass of the positive particles was never less than that of the hydrogen atom and that while the mass of the electron was invariable that of the positive particle was variable. Also the positively charged particles were always at least as large as atoms. He now had enough material available to enable him to proceed with the first attempt to produce a description of the atom itself. He assumed that the atom consisted of a sphere of positive electricity of uniform density inside which the negative corpuscles or electrons were distributed, the negative charge of the latter being exactly balanced by the positively charged sphere.

While Thomson was occupied with this work, other things were taking place in the scientific world which, together with Thomson's discoveries, were to form the foundation of the immense knowledge we have to-day. In 1895 Professor Wilhelm Konrad Roentgen had discovered a new type of radiation which he had termed X-rays and in 1896 Antoine Henri Becquerel had provided the first-known information regarding radio-activity.

But perhaps more important than either of these discoveries was the fact that in 1895 a young research worker from New Zealand arrived at the Cavendish Laboratory. His name was Ernest Rutherford. He came at a time which was exactly right for one of his outstanding genius, and it was not long before he was proving himself worthy of utilising to its fullest advantage the material presented to him by the recent discoveries. His attention, first at Cambridge then at McGill University, Montreal and finally at Manchester was concentrated on radio-activity. The result was that in 1911 he was able to announce to the world his theory of the structure of the atom. It differed from Thomson's model and explained many factors which could not be explained by the earlier theory. The atomic model now described consisted of a very small, positively charged nucleus whose mass was nearly that of the atomic weight of the element in question. Around the nucleus rotated planetry electrons of sufficient number to neutralise the positive charge of that nucleus. In other words, the atom was nothing more than a minute solar system, the relative size of the nucleus and the electronic orbits being largely proportional to the relative size of the sun and planetry orbits of the solar system. It was, however, quickly found that this theory, excellent as it was, did not allow for all the observed phenomena connected with atoms, physical and mathematical. But in 1912 there came to Manchester from Copenhagen, a young Dane, Niels Bohr who quickly proved himself to be a brilliant pupil.

A digression must be made here to refer to the theory enunciated by Max Planck in 1900. He had been studying the results of radiation from hot bodies. He postulated that this radiation proceeded from the atoms in the form of energy. This energy was in the form of discrete particles or quanta and was proportional to the frequency multiplied by a constant, always termed Planck's constant. This relation between frequency of radiation and energy has become one of the fundamentals of science and is the first instance we have of the true, or atomic, energy.

Bohr quickly became fascinated by Rutherford's work and his model of the structure of the atom. He did not remain long at Manchester, but in 1913 produced a Paper in which he showed that the Rutherford atom was not stable and could not exist as Rutherford had at first imagined it. Rutherford had assumed that the same forces which keep the earth in its orbit round the sun would also keep the electrons in their orbits around the atomic nucleus. This was a simple view but was too indefinite from the quantitative point of view. The electrons were not simple solid bodies but electric charges and Clerk Maxwell had shown previously that if an electric charge is accelerated radiation is emitted. Now a body moving in an orbit is being accelerated towards the centre of the orbit, but if this body is an electric charge it would be emitting radiation. According to Rutherford's theory the motion was uniform so the spectrum of an incandescent atom should be continuous, when actually it is discontinuous. The theory did not, therefore, explain the facts. Bohr was in entire agreement with the heavy positively charged nucleus of Rutherford's theory and by weaving the quantum theory of Planck into the Newtonian mechanics of Rutherford's electronic orbits he was able to present a modified atomic model which appeared to explain and allow for the line spectrum of the atoms.

The two fundamental suppositions of this theory are: (1) That for each atom there are a series of orbits around which the electrons rotate, but there are no energy changes, therefore no radiation, and the electron is said

to be in a stationary state. (2) If, however, the electron receives any stimulus from whatever source, it will pass from one orbit to another in the series and in doing so will either absorb or radiate in accordance with the difference between the energy between the two orbits or energy levels, as they are termed. If, for example, hydrogen atoms are subjected to an electric discharge, energy will be absorbed and the electrons will move from the inner level of low energy to an outer one of higher energy. As, however, systems containing least energy are most stable, the electrons will return to the lower energy levels, either by one or more jumps. At each transition, energy is again given out, and this appears as radiation in accordance with the expression $E_1 - E_2 = h\nu$. But it will be seen that this is the expression of Planck's quantum theory for one quanta of radiation which will be monchromatic and a spectral line will result. This, then, is one type of atomic energy; that resulting from the changes between energy levels in the orbits of electrons around the central nucleus.

At first Rutherford rather distrusted this theory of Bohr's but soon became in agreement with it and with some modifications the Rutherford-Bohr atom model still holds good. Opening a discussion on the "Constitution of the Atom" on June 27th, 1914, Rutherford referred to the sizes of nuclei and atoms. About 100 million atoms side by side reach 1 in. and about 1,000 nuclei would stretch across one atom. Thus was Dalton's atom exploded and instead of being bullet-like particles they were now proved to be of as complicated a nature as the solar system itself.

Hitherto the manner by which one atom was distinguished from another was by its atomic weight, that is, by comparing its weight with hydrogen as 1. But now, the distinguishing feature which is even of more importance than the atomic weight is the atomic number. As a result of considerations following a study of radioactive changes, van den Broek in 1911 put forward the theory that each element in the Periodic Table differs from the one before it by possessing one more net positive charge in the nucleus and one more electron in the extranuclear structure. Little attention was paid to this at the time, but in 1913, H. Moseley, a brilliant young physicist working at Manchester, took up the matter and by bombarding atoms of the various elements by cathode rays and by measuring the frequencies of the resulting X-rays, he found that those resulting from the innermost electron orbits, or energy level, increased by uniform steps. Something was always one greater for each advance of elements. Moseley asserted that this was the positive charge on the nucleus of the atom. This assertion has stood the test of all further work on the subject. The atomic number, therefore, is the exact number of net positive charges on the nucleus. Hydrogen, atomic number 1, has, therefore, one positive charge and one electron rotating around the nucleus. Uranium with an atomic number of 92 has in its nucleus 92 times the charge on the hydrogen nucleus, has a net positive charge of 92 and consequently 92 electrons surrounding the nucleus.

Now how are the electrons distributed around their orbits, rings or energy levels? The original work of Bohr has been continued by many workers, and the electrons are now considered to be distributed around quantum groups and energy levels. The entire explanation of this is beyond the scope of this short account of the subject, but it can be said that the number of electrons which can complete an energy level is not the same for all the levels. The stable group of electrons is in accordance with the term $2n^2$ and may, therefore, contain 2, 8, 18 or 32 electrons in accordance with n being equal to 1, 2, 3 or 4, and the successive periods in the Periodic Table are due to this fact. This means that elements of atomic numbers 2, 8, 18 or 32 are entirely stable, but those with numbers either just below or just above these numbers are not stable and are transition elements. The gas helium with atomic number 11 has, therefore, two electrons in the first group or orbit and is stable, similarly the gas neon, atomic number 10 has two electrons in the first orbit and eight in the second which again gives a stable configuration, but sodium with atomic number 11, has one too many for stability. There are also sub-groups to be taken into consideration, but here again the story is rather too long for detailed consideration.

But how is it, it will be asked, that if sodium has an atomic weight of 23 can it possess an atomic number of 11, with presumably a net positive charge of 11 and two electrons in the orbital levels. The answer is that the nucleus of all atoms contains other particles beyond the positively charged ones. In Thomson's day and during Rutherford's earlier work these were supposed to be electrons. Sodium, therefore, would, for an atomic weight of 23, possess two positive charges or protons with 12 negative charges or electrons in its nucleus, thus giving a net positive charge of 11. As the mass of the electron is only 1/1840th of the hydrogen atom, practically the whole of the mass of the atom must, therefore, have been centred in the protons. It is now an indisputed fact, however, that there are no electrons in the nucleus, but that the particles other than the protons are particles bearing no charge, namely neutrons, which have practically the same mass as the proton. Much more will be said about neutrons a little later on. To give another example, iron of atomic weight practically 56, has a net positive charge of 26 with 26 orbital electrons.

The next question with which we are concerned is this—if what has been said is correct, how can we reconcile atomic weights such as 55·84 for iron or 126·92 for iodine with whole number charges? The answer lies in the theory of isotopes. If we find an atom of some element with, say, an atomic weight of 36 and an atomic number of 18, we know at once that the nucleus consists of 18 positive protons with 18 neutrons, surrounded by 18 electrons. But if another atom of the same element is discovered with an atomic weight of 34, yet with the same atomic number, it is obvious that there can only be 16 neutrons in the nucleus. Now the orbital electrons are responsible for the chemical and many other properties of the atoms, so in either of the above cases the element would appear to be exactly the same, yet with different atomic weights. If, now we found that this element occurred naturally with equal numbers of each isotope, by a simple mathematical calculation we shall arrive at the fact that the average atomic weight will be 35. If on the other hand, we find that there are two of the 36 isotopes to one of the 34 type, the resulting atomic weight will come out at 35·33. So that atomic weights containing decimal places are simply the result of the average of a collection of whole number atomic weights, hence, we see that the theory of Prout mentioned earlier, was, in fact, correct. This phenomena of isotopes plays an intensely important

part in that branch of atomic energy which will be considered later.

The picture of the atom can now be summed up thus: It consists of a nucleus with a resultant positive charge equal to the charge on the electrons which rotate around it. These orbits are approximately elliptical and are defined by certain amounts of energy and no other, so that the number of orbits is limited. The energy of the level relative to the nucleus is most conveniently expressed in volts and the unit used is the electron-volt (e.v.) which can be defined as the amount of energy acquired by an electron in moving through a potential difference of 1 volt. Thus, the energy required to move the hydrogen electron from its normal orbit or first level to an infinite distance is 13·54 e.v. The corresponding energies of the outer levels are connected by the relations 1–4, 1–9, 1–16 of the energy of the innermost, or normal level or state. In terms of electron volts these are: 3·38, 1·50 and 0·84. The difference between the first and second levels is, therefore, 13·54 less 3·38 which is 10·16 e.v. If, therefore, some energy change causes the electron to jump from its normal level to the next outer one 10·16 e.v. will have to be expended to do so. The electron does not, however, remain on the second level, but in a microscopical fraction of a second jumps back to its normal orbit and in doing so shoots out a quantum of radiation in accordance with the Planck quantum theory, already explained.

Now is there any practical application of all this theoretical work on the electrons surrounding the nuclei of atoms? The answer is definitely in the affirmative, but it must be admitted that there is still a tremendous amount of work to be done, particularly in respect of the heavier elements and alloys before we can pretend to use this knowledge of sub-atomic structure in any other field than the research laboratory. It has already been pointed out that a stable grouping of electrons contains 2, 8, 18 or 32 electrons but that atoms whose number of electrons are just over or just under these stable groupings are unstable. This means that an atom with, say, one electron above the number required for stability has this one electron held very loosely. As has been stated, the energy of the hydrogen electron is 13·54 e.v., and this is a fairly stable atom, but in helium with two electrons completely satisfying the first energy level the energy is 24·47 e.v., almost double that of the hydrogen electron. But lithium with three electrons has one in the second level and the energy required to remove this, or its ionisation potential as it is generally termed, is only 5·37 e.v. It will at once be seen that this "valency" electron of lithium can be removed very easily, and it can be lost to another element which may be short of an electron for complete stability. As the author was able to show in a lecture given twenty-five years ago, it is due to this that iron occurs in nature generally in the form of an oxide, that it is for the same reason that iron occurs in steel in the state of iron carbide.

In spite of all this, however, and although the Rutherford-Bohr atom explains the Periodic System, the transition groups and many other points, it has been found that there are factors in connection with the atoms, particularly with reference to the heavier ones, that it will not explain satisfactorily. And by explanation, we mean here the mathematical proof of what may otherwise be looked upon as a practical picture of the atom. The question was taken up by de Broglie, Heisenberg, Schrödinger and others with the result that a new class of analytical mathematics was developed known as wave mechanics and matrix mechanics. It is altogether too involved and abstruse to be dealt with here, but for those who have studied this branch of the subject to some extent it should be pointed out that it is very easy to become misled, by what is actually meant by a "wave" theory of matter. It has been shown by Heisenberg that it is impossible by experiment or measurement exactly to define the momentum, position, kinetic energy, etc., of an electron. They cannot be measured accurately at any given time for the reason that the greatest accuracy in obtaining one measurement will affect the electron and there cannot then be accuracy regarding another measurement. Furthermore, it has been shown that the classical mechanics

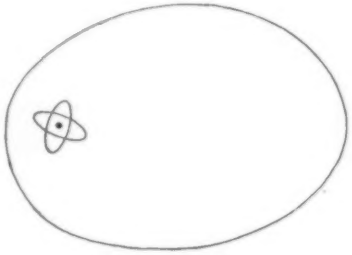


Fig. 1.—Lithium

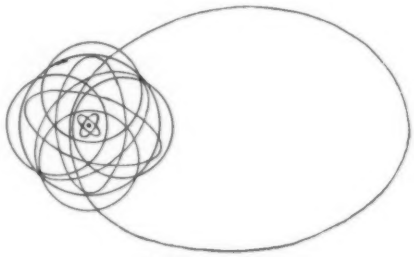


Fig. 2.—Sodium

(after Kramers, from Andrade's "Structure of the Atom").

of a particle in motion in a field of force can be translated into the mathematics appertaining to a ray of light travelling through a medium whose refractive index is varying. Under these circumstances and at times, the particle partakes of the properties of wave motion, but this wave motion does not infer true waves. They are waves of probability and their magnitude is a measure of the probability of an electron being, say, in a certain place at a certain instant. As material particles or perhaps more correctly, as electric charges, the electrons must of necessity travel slower than the speed of light, but in accordance with Planck's quantum theory and under the circumstances mentioned above the speed of these electron "waves" must be greater than the speed of light which is an impossibility. These waves, therefore, transport nothing with them as probability is not material having neither mass nor energy. In short, the waves are not material waves, but are merely a convenient method of describing mathematical equations. From this it follows that it is impossible to define any definite orbit for an electron in any one of its energy levels or stationary states. While Figs. 1 and 2 give a reasonable picture of the orbits of the electrons of lithium and sodium, they infer that the electrons will be just where the orbits are drawn, but to be more exact, these orbits or states should be shown as regions in which there is a reasonable probability of finding an electron in accordance with mathematical calculation. The figures are, however, correct for all practical every-day purposes and show in both instances the loosely bound,

valency electron. Finally, to quote two great authorities on the subject and first Lord Rutherford. He stated in 1934: ". . . it is necessary to be very careful in regarding the electron as a nice little piece of matter. It must be regarded at times as a sort of wave motion." Secondly, Dr. Hume Rothery: ". . . . you have to accept the pattern as a whole and interpret it in terms of probabilities, and you must not ask how the electron moves about inside the pattern."

It all appears, and is, very abstruse and complicated, nevertheless the theories mentioned are fundamental to an understanding, not only of single atoms but also of crystal structure, molecules and alloys.

To be contd.

The Significance of Mechanical Testing

By H. E. Davies, Ph.D., B.Sc., F.I.M. and J. McKeown, D.Sc., Ph.D., F.I.M.

The acceptance of metals for service is generally based on the results obtained from certain mechanical tests, but the significance of these tests is the cause of much discussion and opinions on their importance varies considerably. At a recent meeting of the Midland Metallurgical Societies the subject was discussed; the opening speakers in this discussion were Dr. H. E. Davies and Dr. J. McKeown and a summary of their contributions is given in this article.

OPENING the subject Dr. Davies said that the acceptance of metals for service was generally based upon three physical or mechanical tests, viz., a tensile test, a ductility test, and a shock resisting test. The tensile test was merely a measure of the maximum stress the material would stand in tension; the test for ductility was determined from the elongation of the tensile specimen after fracture, but other ductility tests, such as bend tests, were often asked for; the resistance to shock was generally assessed from the Izod test, where the energy taken to fracture by means of a sharp blow on a notched specimen was measured.

The design of engineering structures was based upon the ultimate tensile stress or its associated properties, yield point and proof stress, but, although certain minimum requirements of ductility and Izod value were demanded, they did not form a direct basis of design. He made it clear that his remarks regarding the significance of mechanical testing referred to its application to ferrous materials. Providing the tensile specimen was of uniform cross-section over its length, the value of the ultimate tensile stress did not appear to be a fundamental value for a particular steel under normal time, temperature and physical conditions. Rate of application of stress did, however, appear to alter the value and this was true also of the yield stress. Results of rapid and slow rates of loading, namely, 0·005 secs., and 2 mins. respectively, to fracture, given by Ginns for carbon steel and by Quinney for mild steel, indicated that with increased rate of loading there was an increase in the ultimate tensile stress. It had also been demonstrated, however, that the tensile strength may increase with a decrease in the rate of loading, Quinney obtaining such results with wrought iron.

It could be demonstrated that a specimen could, in time, extend to fracture under a load less than its "ultimate tensile stress": in fact, there was no such thing as an ultimate tensile stress that was independent of time, because this property depended on stress and time and could occur at lower stress after longer time. This phenomenon, known as "creep" was a complete study in itself.

One could not dissociate ductility measurements, in the form of elongation, from tensile testing and since this largely took place locally on the test piece, the measurement of elongation was not absolute but depended upon the length of the specimen, or the "gauge-length." Also with increase in the rate of loading, the elongation decreased so that its value was dependent on time too. Both tensile strength and elongation were also dependent on regularity of dimensions. If instead of a standard 0·564 in. dia. test-piece, parallel over its gauge-length of 2 in. was substituted a test-piece with a diameter of 0·564 in. at the base of a circumferential notch only, it was found that when this specimen was pulled in tension, it broke with an ultimate tensile stress higher than did the parallel specimen with practically no elongation, and the fracture had become crystalline instead of the usual silky cup and cone type. It had also been found that as the depth of the notch increased, always keeping the diameter at the base of the notch 0·564 in. however, so the tensile strength increased. What significance then had the normal tensile strength and elongation when one had to consider grooved or notched members, such as threaded parts?

Ductility tests could not be dissociated from the tensile test or from the Izod test. They had seen how ductility, as measured by the elongation, was apparently absent in an obviously ductile material when a groove was present on the test-piece. In the same way, the bend test could also be influenced by a groove or notch, when it could reveal a brittle condition existing in the material. Schuster had illustrated this on experiments on samples taken from an overheated crankshaft of 0·30% carbon steel which, mechanically tested in the normal way, gave an elongation of 30·5% and a reduction in area of 50% while the bend test was good. Izod tests, however, gave values of 3·8 and 4·1 and exhibited brittle fractures. Notched-bend specimens were bent and these all failed short and exhibited brittle fractures. and gave an energy of 18·3 ft. lbs. against 32·3 ft. lbs. on a normalised notched-bend specimen. Thus one could see that a brittle condition existing in the material was not revealed by the normal indexes of ductility, the elongation and the bend test. The exhibition of temper-brittleness in steel was another example of this.

It was generally considered that the Izod value was a measure of the shock resisting property of a steel, but

it could be demonstrated that this was far from the truth. It was more accurate to say that it measured the ability of a material to withstand stress concentration at a notch and that it differentiated between a " brittle " steel, or one which fractured with a low absorption of energy and showed a crystalline fracture, and a " tough " steel, or one which fractured with a high absorption of energy and showed a fibrous fracture. It was generally considered too, that the Izod value provided an indication of correct heat-treatment in a steel, because a brittle condition could be produced by faulty heat-treatment, lack of, or imperfect hardenability of a steel could be indicated by brittleness. The Izod value was not a fundamental property of a particular steel because it could be shown that it varied with the size of the bar from which the test-piece was machined. This may, in part, be due to the fact that large sizes were less mechanically worked than smaller sizes, a factor which appeared to have a profound effect upon Izod value but little upon tensile stress. Like ductility, or elongation, the Izod value varied inversely with the tensile strength of steel, but ductility and Izod value were not measures of synonymous properties since it was possible that a steel may be in such a condition as to possess a good elongation but a very poor Izod value.

Within the limits of experimental error one obtained the same value of tensile strength whatever the diameter of the test-piece under normal conditions of testing. This was not the case however, with the Izod value, where the dimensions of the test-piece had a profound effect and could result in the same steel exhibiting either brittle or tough characteristics. A material may behave in a tough or a brittle manner dependent upon the size of the notched bar used, so that the expressions " tough material " and " brittle material " were of doubtful validity and should only be used to describe the behaviour of material under standardized conditions of the test.

The Izod test may then differentiate between a tough state and a brittle state, the former giving a fibrous fracture with a high value of absorbed energy and the latter a crystalline fracture with a low value of absorbed energy. In fracturing a tough material, much tearing and bending took place, but the Izod test did not reveal how the energy was distributed in fracturing, tearing and bending.

Schuster had made an extensive examination of the mechanism of fracture of notched-bar specimens and the results on a nickel-chromium steel, heat-treated so as to be temper-tough in one specimen and temper-brittle in another were of interest. His load deflection diagrams were obtained on slow notch-bend tests, due to the difficulty of carrying out the procedure on the Izod test, but comparable results were obtained. Schuster's diagrams indicated that the actual loads required to break both the tough and the brittle specimen were practically the same, 2,050 lbs., against 1,920 lbs., the energy absorbed to the peak of the curve was 15·75 ft. lbs. for the tough specimen and 8·5 ft. lbs. for the brittle specimen, whilst the tough specimen required 49 ft. lbs. to extend the fracture and tear the piece asunder, the brittle specimen requiring only 1 ft. lb. This confirmed that the Izod test was by no means a shock test, since the greater part of the energy expended in breaking a tough specimen was absorbed in tearing the pieces apart, whilst the energy to produce incipient fracture, and also the fibre stress, were practically the same for a steal exhibiting either tough or brittle behaviour.

Comparing the notch-tough nickel-chromium steel with a rimming steel which gave an Izod value of 75 ft. lb., the load/deflection diagram showed that 35·2 ft. lb. were absorbed up to the peak on this steel, compared with only 15·75 ft. lb. on the nickel-chromium steel, indicating that to initiate fracture the notch-tough carbon steel is superior although they both have approximately the same Izod value. A high Izod value could thus afford no guarantee that the material had a satisfactory resistance to initial fracture.

Compared again with a normalized 0·30% carbon steel which gave an Izod value of 30 ft. lb. and broke with a " brittle " fracture, the energy absorbed up to the peak of the curve was 20 ft. lb. for this notch-brittle carbon steel against 15·75 ft. lb. for the notch-tough alloy steel. The term " notch-brittle " may thus be quite misleading, for this carbon steel was brittle since it broke with a crystalline fracture on the Izod test, although its Izod value of 30 ft. lb. was due to its high resistance to early fracture.

The Izod value, therefore, could not be considered to be a criterion of the resistance of a metal to start failure under notch concentration, since the difference in the energy absorbed by a notch-tough steel over that of a notch-brittle steel was largely made up of energy to extend incipient failure and such notch-brittle steels may offer just as much resistance to the start of a crack as would a notch-tough steel.

It had been seen, however, that, both in the case of the overheated crankshaft and the temper-brittle alloy steel, it was only the Izod test which had indicated the brittle condition of these steels, so that wherever, in practice, there was a possibility of a brittle fracture occurring the Izod test was essential.

If a material never showed a brittle fracture the test revealed nothing which a normal tensile test could not indicate and its use on a material which had a small reduction in area at fracture was also quite useless because such a material must possess a low impact value. It had been seen that the Izod value fell with increase in the size of the bar, and also how reduced notch-toughness, with brittle fractures, was attained by increasing the size of the test-piece. How would these factors affect the failure of parts, particularly of large section ? The importance of dimensions in influencing the type of fracture could not be overlooked. Greaves had said, in an analysis of service failures, that " . . . the number of cases in which the material gave poor notched-bar tests was much too large for the association to be accidental."

The other opening speaker, Dr. McKeown, said that the performance and life of a component part of a structure or of a machine in service depended on a number of factors only some of which could be satisfactorily related to the results of mechanical tests on the material or materials from which the component was constructed This was particularly the case when the component was the subject of conditions referred to in a general way as " fatiguing " conditions. In many such cases in service incomplete information was available on such factors as, the actual range of alternating stress, the frequency of stress alternations, the occurrence or absence of bursts of higher stressed of the same or of a different frequency from that of the more general level of alternating stressed and the

presence or absence of a steady state of stress in the same or in a different direction to the alternating stress.

The wider use of electric strain gauges was helping considerably to increase the engineer's knowledge of the stresses present in his structures and of their frequency. While in general at temperatures low relative to the melting point of the material the frequency had little effect on the fatigue endurance, at elevated temperatures evidence was gradually accumulating to show that the frequency of application of stress or of strain may have a very considerable effect. Also, at elevated temperatures, the effect of a mean stress other than zero, when creep may occur, may be considerable. The mechanical properties of the material used in constructing a component may be taken as a guide in design. When fatigue resistance was being considered, tests on the material may show the effect of such things as, first, the surface finish. This could be divided into mechanical and metallurgical, including the influence of machining finish, sandblasted finish or pickle finish or alternatively degree or polish, also oxidation, decarburisation, etc. Secondly, there would be shown the sensitivity to notch effects, produced by lack of fillets, by keyways, holes and so forth. Thirdly, environment such as corrosive or non-corrosive, or fretting or surface abrasion and, lastly, temperature. It was the effect of temperature on which Dr. McKeown directed particular attention.

Effect of Temperature on Fatigue Resistance

Early work showed that, in the case of steels, a moderate increase in test temperature resulted in no noticeable decrease, in fact, in some cases, an increase in the fatigue limit. The range of temperature covered in this early work was not very great, and seldom exceeded some 400 to 500° C. The present need was for information on the fatigue properties at higher temperatures of the materials used in gas turbines, and here results in the temperature range 700 to 1,000° C. or even higher were called for. At the same time some work was needed on materials at the lower temperatureswith reference to the use of such material in superchargers and compressors of gas turbines. Temperatures here may range from 200 to 500° C.

Valuable pioneer work was carried out in Sheffield by Professor F. C. Lea on the high temperature fatigue properties of steels using the Haigh machine at a frequency of 2,000 cycles per min. Professor Lea and Dr. Budgen in a report to the British Association in 1924 gave valuable correlative data on the creep and fatigue of a number of steels in the temperature range 15 to 800° C. Lea and Budgen drew attention to the effects likely to result from running fatigue tests at lower speeds at elevated temperatures where creep was continuous. At high speeds they found that the upper stress of the stress range could be well above that stress which if continuously applied would produce continuous creep and yet failure would not occur in the repeated stress test in 50 $\times$ 10^6 cycles. Moreover when the temperature was high enough to produce continuous creep a definite fatigue limit was not found, the S/Log n curve continuing to drop slowly.

Mr. H. J. Tapsell, at the N.P.L., showed that in mild steel at temperatures above 300° C. the fatigue properties were considerably influenced by the rate of alternations of stress. In 1932, Schwinning and Strobel in Germany, working on hard drawn aluminium over a temperature 1 to 300° C., found that there was no appreciable change in endurance limit until the temperature at which recrystallisation commenced was exceeded. In June, 1939, Gurther and Schmid published results of endurance tests at high temperatures. They found that in steels, the creep strength, i.e., the stress to produce a given rate of creep and a total creep strain not exceeding a given amount, decreased rapidly with increasing temperature, whereas the endurance limit based on 2 $\times$ 10^6 cycles of stress remained about the same until a temperature was reached at which it was greater than the creep strength, after which it fell. They found similar effects with other materials. They stated that the critical temperatures at which fatigue strength and creep strength were equal was below room temperature for pure copper, pure zinc, lead and lead alloys, the fatigue strength at room temperature of these materials being greater than the creep strength. For most alloys at room temperature the creep strength is so high that, except at very high mean stresses, life was determined by the fatigue strength. They concluded that in all materials above a critical temperature, depending on the material, the life was determined not by the creep strength at high mean stress, but by the fatigue strength at zero or low mean stress. At higher temperatures the life was determined by the creep strength except at zero mean stress.

Summarising the above observations, Dr. McKeown arrived at the following conclusions: A fatigue limit was not obtained and an endurance limit, i.e., a stress corresponding to a predetermined number of stress cycles, had to be determined. The effect of speed of stress or strain reversals was very important and the life is dependent on the mean stress and if this was sufficiently high was determined by considerations of creep resistance.

Interesting information on the effect of testing above the critical temperatures could be obtained from work on lead at room temperature. Fatigue failure was transcrystalline in most metals at room temperature whereas in lead it was intercrystalline. However, in other metals, if the test temperature was sufficiently high, the fatigue failure was intercrystalline.

The effect of speed was quite noticeable in tests on lead, as had been shown by Professor H. F. Moore and his colleagues in the University of Illinois and by Ferguson and Bouton in the Bell Telephone Laboratories. Testing under conditions of specific strain Moore showed the effects of working at 248, 44, 6 and 1 cycles per minute. No fatigue limit was indicated at any of these speeds. It was also clear that reducing the speed reduced the number of reversals to failure at any particular value of reversed strain. Ferguson and Bouton showed similar effects, again under conditions of specific strain.

Dr. McKeown then moved on to consider an aspect of fatigue testing at elevated temperatures which may have important bearing on the type of test which should be used to give information of the sort needed by a designer. Fatigue tests may be carried out and fatigue in service may occur under two distinct conditions. These were, conditions or specific stress or conditions of specific strain. In fatigue testing the simple example of the first was that found in the rotating Wohler test. The single point loading cantilever specimen was subjected to a constant and specific bending moment giving rise to a constant and specific stress. That was particularly the case when the stress was within the elastic range of

the material tested. It could be carried out in another way, one end of the specimen being clamped so that it did not rotate while the other end was subjected to a constant strain or deflection, this strain rotating so that the end of the specimen was forced to move on a circular path in space. In this case the specimen was subjected to conditions of specific strain. Within the elastic range of stress and strain of a specimen and provided that no change occurs in the stress-strain relationship of the specimen as a whole during the test, there would be no difference between the results of the two forms of test. But outside the elastic range and especially at stresses where creep may occur the two tests may give different results. This latter condition may well occur at elevated temperatures.

Under conditions of specific strain once failure commenced the stress in the specimen falls and due to this the time of test, i.e., the endurance of the specimen, may be increased considerably beyond that when strictly specific stress conditions were observed. He knew of no test where the conditions of specific stress were rigidly adhered to in the Wohler test with rotating specimen, as soon as a crack was initiated the stress rose sharply. Similar conditions apply in the Haigh test.

It may therefore become necessary for the designer to consider whether the conditions in service to which the particular part under consideration is subjected are those of specific stress or specific strain. He would quote one or two examples. An electric cable carried by a bridge would move with the bridge and hence be subjected to fatiguing action under specific strain conditions. A similar cable suspended in air would vibrate, due to wind currents, etc., through an amplitude which was governed by the elastic stiffness of the cable, i.e., would be fatigued under conditions approaching those of specific stress. A spring may be used to restrain the movement of a component, and in so doing may be subject to fatiguing action under conditions of specific load variation, i.e., specific stress variations in the spring, or under conditions of specific deflection, i.e., specific strain variations in the spring.

Dr. McKeown then drew attention to a new fatigue machine developed for high temperature fatigue testing in the laboratories of the British Non-Ferrous Metals Research Association. This machine utilised the Wohler principle of a cantilever subjected to a single point loading. The specimen was stationary while the load rotated, the load being produced by a small out-of-balance weight carried on the rotating housing of a ball-race attached to the end of the specimen or an extension of the specimen. Since the specimen was stationary, it was a simple matter to measure its temperature accurately. Provided that the speed of rotation of the out-of-balance weight was constant, the conditions of specific stress were attained. The stress was measured by observing in the measuring microscope a band of light the length of which was proportional to the deflection of a point on the specimen. The specimen was previously calibrated under static bending conditions so that the relationhip between deflection—at the same point—and bending moment (hence bending stress) was known. Constant speed of revolution of the out-of-balance weight was essential to constancy of stress and this was attained by the use of a special D.C. motor with governor control, the governor operating to change the resistance of the motor field. Due to frequency variations in the electricity supply synchronous motors did not give sufficiently close constancy of speed.

Forthcoming Meetings

Institute of Metals. *Birmingham Section.* Film on "Metal Spraying" and talk on "Protective Coatings," by W. E. Ballard, on November 27th, at 6-30 p.m., at James Watt Memorial Institute. *London Section.* A special meeting arranged for November 27th, at 7 p.m., at 4, Grosvenor Gardens, London, S.W. 1, at which Dr. W. J. Kroll will give an address entitled, "Malleable Titanium and Zirconium"—Two metals of the future made on a commercial scale. (Dr. Kroll is consulting metallurgist to the Bureau of Mines, Albany, Oregon, U.S.A.). *Sheffield Section:* "Magnesium Alloys," by A. J. Murphy, M.Sc. in the Mining Lecture Theatre, Department of Applied Science, the University, St. George's Square, on November 21st, at 7-30 p.m.

West of Scotland Iron and Steel Institute. "The Selection and Use of Steel for Steam Turbines," by Dr. C. Sykes, D.Sc., Ph.D., November 21st, 6-45 p.m. "Maintenance of Steel Works Plant," by G. S. T. Martin, December 19th, 6-45 p.m. Meetings held at 39, Elmbank Crescent, Glasgow.

Institute of British Foundrymen: *Birmingham Branch.* "Graphite Formation in Cast Iron," by H. Morrough. James Watt Institute, Great Charles Street, Birmingham, November 26th, 7-15 p.m. *Sheffield Branch.* "Ferrous Die Casting," by C. D. Pollard, H. A. Redshaw and C. A. Payne, Royal Victoria Hotel, Sheffield, December 8th, 7-30 p.m.

Royal Aeronautical Society. "Problems Facing Civil Airline Operations," by N. E. Rowe, C.B.E., B.Sc., D.I.C., F.R.Ae.S., December 4th, 6 p.m., Institution of Civil Engineers, Great George Street, London, S.W. 1. "The Work of the High-speed Tunnel," by Prof. A. Thom., M.A., D.Sc., and W. G. A. Perring, F.R.Ae.S., December 18th, 6 p.m., Institution of Civil Engineers, Great George Street, London, S.W. 1.

Institution of Mechanical Engineers. Thomas Hawksley Lecture on the "Rocket as a Weapon of War in the British Forces," by Sir Alwyn Crow, C.B.E., on November 21st, at 5-30 p.m.

Ebbw Vale Metallurgical Society. "Electrolytic Tinning," by W. D. Jenkins, B.Sc., November 25th, at 7 p.m., Lesser Workmen's Hall.

Sheffield Metallurgical Association. Professor L. Aitchison will present a paper on November 25th, at 7 p.m. Discussion on "Ingot Surface Defects," to be opened by Mr. T. Arnold (Hadfields, Ltd.), Mr. N. H. Bacon (Steel, Peech and Tozer, Ltd.), Mr. G. E. Howarth (English Steel Corporation, Ltd.), December 16th, at 7 p.m. Meetings are held at 198, West Street, Sheffield.

Manchester Metallurgical Society. "Some Metallurgical Problems in the Field of Atomic Energy," by E. W. Colbeck, M.A., F.I.M., Hadfields, Ltd., Sheffield. (Joint Meeting with the Iron and Steel Institute and the Institute of Metals). November 26th at 6-30 p.m., at the Engineers' Club, Albert Square, Manchester.

Hydrogen, Nitrogen and Oxygen in Ferrous Metals

Their Properties and their Determination—Part II

By E. C. Pigott

A very extensive literature exists on the gaseous constituents of irons, steels and ferro-alloys. Over a period of many years leading chemists and metallurgists have been engaged in piecing together the intricate facts brought to light. It would now seem that the main experimental and co-ordinating work has been done and that a clear perspective of this once totally obscure field has become possible. Such a perspective was commenced in our last issue and is continued in the present and subsequent articles.

Determination of Hydrogen in Steels and Irons by the Hot Extraction Method of Colbeck and Craven

The whole apparatus, except for the furnace tube and side-arms, is constructed from Pyrex glass, the mercury-vapour pumps, the Töpler pump and the McLeod gauge being sealed on in position. The furnace tube is of transparent silica. All taps and joints are greased with Apiezon grease M.

The Method

(Accuracy ±0·00003%).

(Time required (actual determination) about 1½ hrs.).

Principle: Evacuation at an elevated temperature and measurement by volume and pressure.

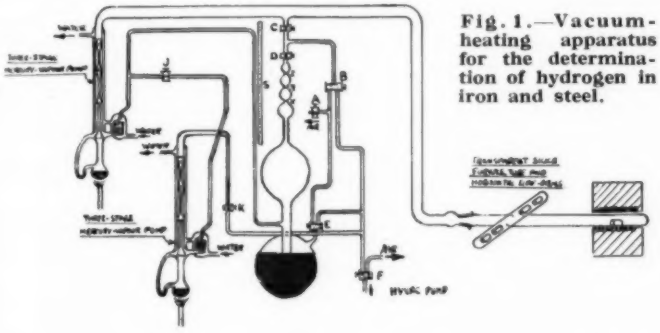


Fig. 1.—Vacuum-heating apparatus for the determination of hydrogen in iron and steel.

The apparatus is assembled as in Fig. 1, the cleaned and weighed specimens being in one of the side arms. Taps C, D, J and K are opened; tap A is closed. Taps B and E are then opened to vacuum, and with tap I closed, the Hyvac pump is started up and the buffer system between it and tap I evacuated. Tap F is then slowly opened to the system, and pumping is continued until most of the air has been evacuated from the apparatus. The two three-stage mercury-vapour pumps are then started up, and taps B and G are closed.

The furnace is brought up into position, switched on, and its temperature raised to 600°–650° C. The outgassing process is continued, preferably overnight. Taps F, J, K, C, and D are then closed. After tap A has been opened, tap E is also opened cautiously to admit air into the top of the mercury reservoir and so to force the mercury upwards into the second large bulb of the Töpler-McLeod unit and thence into the calibrated bulbs.

The mercury level is carefully adjusted to the higher calibration mark Z and the difference in height between this mercury column and that in the adjacent tube is read off on the scale S. Any difference in height between the two mercury columns at this stage indicates either a leak in the apparatus or incomplete evacuation. In the absence of any difference in level, the mercury is brought back into the bottom reservoir of the Töpler-McLeod unit by opening tap F to the Hyvac pump and drawing the air from the reservoir by opening tap E to vacuum. Taps F and E are then closed again and a blank on the apparatus is determined by collecting the gas delivered by the three-stage mercury-vapour pump in one hour (austenitic samples take longer) and measuring its volume and pressure in the manner outlined above. This blank should never exceed 0·0005 ml. per hour and is generally much smaller than this maximum figure. If the blank figure is satisfactory the determination of hydrogen in the sample can follow.

The furnace is drawn back to expose the full length of the furnace tube, and the specimen is brought up to a pre-determined mark by means of a permanent magnet (using for non-magnetic samples a magnetic pusher from which the hydrogen has been previously removed.) The furnace is now brought back into position. The gas evolved in a given time is then collected and compressed into the calibrated bulbs, and its volume and pressure are noted. A single sweep only of the Töpler pump is taken; this collects about nine-tenths of the gas actually present. Heating of the specimen is continued until the evolution of gas ceases. Final pressure readings are then obtained. After about 30 mins. the rate of evolution decreases to a very small value. It is usual to allow at least 60 mins. for the heating and complete degasification of the specimen.

The apparatus is brought back to atmospheric pressure in the following way: At the conclusion of a series of tests, the mercury is brought into the lower reservoir of the Töpler pump, taps E and F are closed, taps J and K are opened, and the burners beneath the mercury-vapour pumps are turned off. Taps C and D are closed,

and taps A and B opened to admit a small volume of air after which tap A is again closed. After cautiously opening tap E, so causing a slight rise in the mercury towards the second large bulb of the Töpler-McLeod unit, and then balancing this by opening tap C a little, taps C, E and D can be fully opened and the inlet of air controlled by manipulating tap A.

The factor for converting direct percentage to ml. per 100 g. is 11,200. The factor for converting direct percentage to atomic percentage is 56 (e.g., 0·0001% hydrogen = $1 \cdot 0 \times 10^{-4}$ % = 1·12 ml. per 100 g. steel = 0·0056 atomic percentage = 0·087 ml. per ml. of steel).

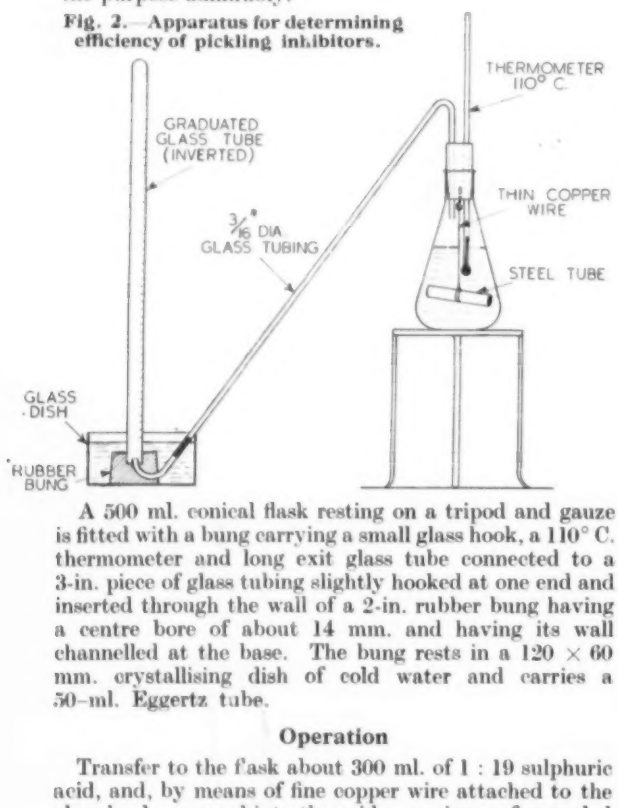
Theory of the Method

α-Iron is particularly permeable to hydrogen at temperatures above 500° C., the rate of evolution in vacuo attaining a slight maximum at 650° C. The extracted gas is virtually pure hydrogen and seldom calls for examination in respect of impurities.

Evaluation of Pickling Restrainers by Determination of Hydrogen Evolved

The efficiency of the recommended dosage of the various acid-pickling restrainers, proprietory and otherwise, varies from about 60% up to practically 100%. It is useful to be able accurately and rapidly to assess their efficiency not only as a means of comparison but also for arriving at the optimum dosage. Loss-in-weight methods are crude and where speed and accuracy are of consequence it is far preferable to measure the acid attack of the metal in terms of the hydrogen evolved. The simple apparatus shown in Fig. 2 serves the purpose admirably.

Fig. 2.—Apparatus for determining efficiency of pickling inhibitors.



A 500 ml. conical flask resting on a tripod and gauze is fitted with a bung carrying a small glass hook, a 110° C. thermometer and long exit glass tube connected to a 3-in. piece of glass tubing slightly hooked at one end and inserted through the wall of a 2-in. rubber bung having a centre bore of about 14 mm. and having its wall channelled at the base. The bung rests in a 120 × 60 mm. crystallising dish of cold water and carries a 50-ml. Eggertz tube.

Operation

Transfer to the flask about 300 ml. of 1 : 19 sulphuric acid, and, by means of fine copper wire attached to the glass hook, suspend into the acid a specimen of annealed and descaled* mild steel having a surface area of about 20 sq. cm.— e.g., a $2\frac{3}{4}$ in. piece of $\frac{1}{2}$ in. bore 18 S.W.G. steel tubing. Raise the temperature to 70° C., and after about 5 mins. insert the inverted Eggertz tube, filled with water, into the 2 in. bung so that it just clears the hooked end of the 3 in. piece of tubing. Take the difference in readings over a period of, say, 1 min. Convert into terms of ml. of hydrogen evolved in 1 hr. (Yield A.).

Repeat after the addition of restrainer, and after inserting a fresh identical specimen. Take the difference in reading over a period of, say, 15 mins. and convert into terms of ml. of hydrogen evolved in 1 hr. (Yield B). Then, percentage efficiency = $\left\{\frac{A - B}{A}\right\} \times 100$

If descaling time tests are also carried out, employing progressive dosages of restrainer, the most favourable dosage, representing a compromise between rate of descaling and restraining efficiency, can readily be calculated. A typical optimum dosage is 1 pint per 200 gallons of dilute acid.

NITROGEN

At Wt : 14·008 (weighted mean of N-14, N-15 and N-16.
M. Pt. : −209·8 C.
B.Pt. : −195·8 C.
Density (air=14·40) : 14·01.
Oxides : N_2O, NO, N_3O_4, N_2O_3 $NO_2 \rightleftharpoons N_2O_4$, N_2O_5, NO_3, $N_2'O_7$.
Sol. (1 ml. water at O.C.) : 0·024 ml.
Allotropes : molecular, atomic, tri-atomic.
Discovered 1772 by D. Rutherford.

Extraction

Elemental nitrogen forms 78·06% of the air. Only a few minerals contain appreciable amounts of combined nitrogen. The outstanding deposit in compound form occurs in Chile as crude sodium nitrate. Nitrogenous substances are present in all fertile soil, natural waters, and a great many animal and vegetable products. The element is readily obtained, in an impure form, by removing the admixed carbon dioxide and oxygen from the atmosphere. A product free from the rare gases is obtained by the fractional distillation of liquid air. When producer gas and steam are passed through a heated catalyst and the resulting nitrogen-hydrogen-carbon dioxide mixture is freed from carbon dioxide by agitation with water under pressure, a product is obtained which, after enrichment of the hydrogen content, is suitable for the Haber synthesis of ammonia.

Chemical Properties

Nitrogen is a colourless, tasteless, odourless, incombustible and neutral gas, non-poisonous but unable to support respiration. Under ordinary conditions and at temperatures below 200° C., the element is decidedly unreactive. At high temperatures and pressures, it will combine directly with oxygen, with hydrogen, and with many metals. The stability of its hydride (ammonia) marks nitrogen off from the other elements comprising Group VIb. in the periodic table. Normally, nitrogen is trivalent.

Solid nitrogen has a density of 1·0265, an atomic volume of 13·6, an atomic radius of 0·71 and an atomic frequency of 1·9.

* Descaling must be carried out in the absence of inhibitor, and followed by heating at 100°–200° C. for 30 mins. or so in order to expel hydrogen.

Atomic (metastable) nitrogen, produced when a silent electric discharge is passed through the gas at low pressures, is one of the most chemically active of all the elements. Whereas ordinary nitrogen is molecular, active nitrogen is atomic. A third allotrope, triatomic nitrogen, is obtained when the ordinary and active forms combine.

Hydrides

Nitrogen forms three hydrides: ammonia, NH_3: hydrazine, N_2H_4 and hydrazoic acid, N_3H. Very large quantities of ammonia are obtained from the ammonical liquors of the gas works and recovery coke-oven plant. In the Haber synthesis, a 1 : 3 mixture of nitrogen and hydrogen, under a pressure of 200–300 atmospheres and at a temperature of 500° C. is brought into contact with a suitable catalyst, e.g., pure iron with small proportions of sodium oxide and silica. Ammonia is also formed by the hydrolysis of nitrides, a technical method. It is a comparatively stable gas at ordinary temperatures but at a dull red heat begins to decompose into its constituent gases. The gas does not support ordinary combustion: it burns in oxygen with a yellowish flame. Its density is little more than half that of air. It liquefies readily under pressure; liquefied ammonia boils at −33·5° C. and solidifies to white transparent crystals at −78° C.

In the presence of red hot platinum, ammonia may be oxidized by air or oxygen almost completely to oxides of nitrogen.

Ammonia is extremely soluble in water, one volume of water at 20° C. dissolving 710 volumes of the gas; solution is accompanied by the formation of some ammonium hydroxide and by the generation of heat. The strong basic character of its aqueous solutions, as shown in the neutralizing of acids with formation of salts or in the precipitation of metallic hydroxides, is perhaps the outstanding property of ammonia.

Unless containing a coloured acid radical, ammonium salts are white. The perchlorate, cobaltinitrite and chloroplatinate excepted, they are readily soluble in water. They decompose or volatilize below red heat.

Hydrazine, a powerful reductant, is derived from ammonia by substitution of a hydrogen atom by the NH_2 group, and is obtained on heating the ammonia with sodium hypochlorite. It is usually isolated in the form of its sulphate, which has a solubility at 22° C. of 3%.

Hydrazoic acid, obtained on treating hydrazine with nitrous acid or on oxidizing mixtures of hydrazine and hydroxylamine with hydrogen peroxide, is stable in aqueous solution, but explodes when the anhydrous acid is shaken or warmed. The acid is equal in strength to acetic acid; it boils at 37° C. and solidifies at −80° C.

Halides

Many of the nitrogen halides are explosive. The chief among them are NH_2Cl, NH_2Br, $N_2H\,I_3$, NF_3, NCl_3 and NI_3, obtained by substitution of the hydrogen in ammonia by halogen, and also N_3Cl and N_3I.

NCl_3 and NBr_3 are very unstable, decomposing in the presence of excess of ammonia with liberation of free nitrogen. NI_3 is more stable; it is insoluble and is brownish-black in colour. These tri-halides tend to combine loosely with another molecule of ammonia. Nitrogen fluoride, a gas, is much more stable and is non-explosive.

Iodine azide, N_3I, which is of a pale yellow colour, is produced by the action of iodine on AgN_3, it is even more explosive than NI_3 and is quite soluble in water, undergoing hydrolysis.

Chlorozide, N_3Cl, is analogous in behaviour; it is prepared by acidifying mixed solutions of sodium azide and hypochlorite with weak acids, and is extremely explosive.

Oxides

The properties of the oxides are summarised in Table I.

TABLE I.

	Nitrous Oxide	Nitric Oxide	Nitrogen trioxide	Nitrogen tetroxide	Nitrogen pentoxide
Formula	N_2O	NO	N_2O_3	N_2O_4	N_2O_5
Normal State	Gas	Gas	Gas	Liquid	Solid
Colour	Colourless	Colourless	Reddish-brown	Varies with temperature	White
M.Pt. °C.	−102·4°	−161°	−103°	−11·5°	30°
B.Pt. °C.	−89·5°	−142·5°	3·5°	21·3°	47°
Acid	$H_2N_2O_2$	H_2NO_2	HNO_2	—	HNO_3

The oxides NO, N_2O_3, and $NO_2 \rightleftharpoons N_2O_4$ bear the closest relationship to each other: one oxide may be converted into another very readily and they are all obtained by the reduction of nitric acid. Nitrogen peroxide gradually decomposes, even at room temperature. The corresponding acid, nitric acid, is obtained from the action of sulphuric acid on Chile saltpetre, by combination of the nitrogen and oxygen of the air, or by the catalytic oxidation of synthetic ammonia.

Pure nitric acid (100% HNO_3) is a colourless, unstable and very hygroscopic liquid, having a specific gravity of 1·53; when mixed with water, it contracts in volume and generates heat. It boils at 86° C. and freezes at −42° C. to a white solid. The constant boiling liquid, which corresponds roughly to the formula HNO_3, $2H_2O$ but is actually a mixture of HNO_3, H_2O and HNO_3, $3H_2O$, has a boiling point of 120·5° C.; it contains 68% of HNO_3 and has a specific gravity at 15° C. of 1·414. It is so powerful an oxidant as to oxidize sulphur to sulphuric acid and phosphorus to phosphoric acid.

Nitrates other than those of natural occurrence are almost exclusively obtained by the action of the free acid on metals, oxides or carbonates. The gradual decomposition of nitric acid is due to the presence of small quantities of free N_2O_5. Nitrites, from HNO_2, are seldom made by using a solution of the pure acid; rather are they obtained by decomposing the nitrite of barium or silver with the sulphate or chloride of the metal in question.

Nitrides

Many metals combine with nitrogen at a dull red heat or above, forming trivalent nitrides, e.g., Mg_3N_2 Ca_3N_2, Ba_3N_2, Mn_3N_2, which are decomposed by water with formation of ammonia. Nitrides of the metals of Groups III, IV and V are formed on heating in a limited supply of air, preferably in the presence of a little carbon, but with the exception of beryllium, not those of Groups I and II. The alkali metals combine only if the nitrogen is of the active variety. Nitrides of metals of Group VI cannot be made synthetically. When heated in a stream of nitrogen, carbides are converted into nitrides.

Nitrogen and solid iron do not form a nitride, but Fe_2N is produced by the action of ammonia. AlN is formed when alumina is heated with carbon to 1,800° C in nitrogen. Silicon combines readily to form the

nitride Si_3N_4. Titanium forms TiN at 800° C. When heated in nitrogen, solid manganese forms Mn_5N_2 heated with ammonia it forms Mn_3N_2. When boron is burnt in nitrogen or heated in ammonia, BN is formed ; it is decomposed by steam into boric acid and ammonia.

The nitrides of silicon, phosphorus and boron (Si_3N_4, P_3N_5, BN) are distinguished by extreme stability. Those of silicon and boron, which are highly polymerised, are amongst the most refractory of substances (M.Pt. 1,900° C. and 3,000° C. respectively). The higher the temperature to which they have been heated, the more difficult it is to decompose them. Dilute acids or alkalis are without action ; decomposition takes place in molten caustic potash. Phosphorus nitride decomposes at a bright red heat.

Sulphur nitride (S_4N_4) and copper nitride are unstable, particularly the former. Copper nitride decomposes at 300° C.

Metal nitrides are often characterised by great stability. Only the most noble metals and some of the metals of medium affinity (e.g., tin, nickel, and cobalt) fail to form nitrides. The nitrides of many metals besides those of Group III contain only one metal atom and one nitrogen atom, e.g., those of titanium, zirconium, niobium, tantalum and vanadium ; these compounds being not ionic but non-polar. They are particularly stable and are virtually insoluble in hydrochloric acid. Iron nitride is readily decomposed by mineral acids. Many nitrides are decomposed by moisture ; to these belong the nitrides of aluminium, AlN, zinc, and magnesium, Mg_3N_2. The manganese and tungsten compounds, Mn_3N_2 and W_2N_3, are only slowly attacked by water. Se_4N_4, like S_4N_4 and S_5N_2, is insoluble in water. Chromium nitride, CrN, more stable than iron nitride, is not decomposed by water at 220° C. Decomposition is favoured by caustic alkalis which, however, only slowly attack zirconium nitride. Acids generally act as better solvents than water. The nitrides of aluminium, beryllium, titanium, zirconium, vanadium, niobium, and tantalum melt between 2,000° and 3,000° C ; calcium nitride, Ca_3N_2, has the lowest melting point at 900° C. The nitrides of the more noble metals decompose more readily : thus copper nitride decomposes at 300° C. All are difficult to reduce, even in the presence of hydrogen. Mercury, lead, bismuth, aluminium, silver, antinomy, etc., yield nitrides on ammonolysis in liquefied ammonia.

Tests

Gaseous nitrogen is usually identified negatively, i.e., by its failure to respond to tests for other gases. An incombustible gas that does not support combustion, is neutral, and does not react with any ordinary reagent is probably nitrogen. Confirmation is usually sought. Perhaps the best confirmatory test is to pass the suspected gas over heated calcium and to identify the calcium nitride produced, by its reaction with water to form lime and ammonia. After removing other gases, the remaining nitrogen and inert gases may be measured together volumetrically. Nitrogen may be detected by means of the spectroscope. The percentage of nitrogen in a compound is often determined by the Kjeldahl method, in which the ammonium sulphate generated by boiling with conc. sulphuric acid is boiled with alkali and the evolved ammonia collected in standard acid. Nitrogen in nitrates or nitrites (or in organic compounds containing a nitro group) which do not form ammonia with sulphuric acid and to which, therefore the Kjeldahl process is inapplicable. can be determinec by the use of Devarda's alloy (45Al50Cu5Zn) whicl in the presence of alkali reduces them to ammonia.

Ammonia

Ammonia is easily detected by its pungent characteristic smell as well as by its alkaline reaction. No other gas (except methylamine and ethylamine) has an alkaline reaction.

Salts of ammonia are decomposed by heating their solutions with a strong base such as the hydroxides of the fixed alkalis or the alkaline earths. Tartaric acid produces, as with potassium, a white precipitate soluble in the presence of alkalis or mineral salts.

An extremely delicate test is afforded by Nessler's reagent, which added to a solution containing ammonia, combined or free, produces, fairly rapidly but not instantaneously, a yellow to orange-brown product of $NH_2Hg_2I_3$, H_2O which remains in colloidal solution or flocculates to form a precipitate. The intensity of the colloidal coloration is proportional to the amount of ammonia present : any comparison must be made before flocculation occurs.

Ammonia may be estimated gravimetrically by precipitation as $(NH_4)_2PtCl_6$.

Ordinarily, ammonia is determined by titration using methyl orange as indicator. That present in an ammonium salt is determined by distilling the salt with excess of caustic soda, passing the distillate into a known volume of acid and afterwards determining the excess of acid by titration.

Added to a solution of copper sulphate, ammonia yields a pale blue precipitate of copper hydroxide, which dissolves in excess of ammonia to give a deep blue liquid, a well-known test in concise form.

Nitric Acid : Nitrates

All known inorganic nitrates dissolve readily in water : even that of lead. The brown ring test is often applicable.

Nitrates are reduced to ammonia by means of aluminium, zinc, or, most conveniently, by finely divided Devarda's alloy in strongly alkaline solution. Arndt's alloy (60 Mg : 40 Cu) quantitatively reduces nitrates in neutral solution to ammonia.

Nitrates may be precipitated from nearly boiling solutions as nitron nitrate $C_{20}H_{16}N_4HNO_3$ (sol. at 20° C., 0·1g.p.l) by addition of the base diphenyl—endo-anilo-hydro-triazole (" nitron ") in the form of a 10% solution in 1:20 acetic acid. Since the sulphate and acetate are soluble, precipitation may be made in sulphuric acid or acetic acid solution. After several hours' standing, the precipitate may be collected on a sintered glass crucible, dried at 105° C. and weighed ; the nitrate (NO_3) content is 16·52%.

A test suitable for quantitative determination and applicable to all metals and nearly all salts consists in adding to a volume of about 10 ml., 1 ml. of a 0·02% solution of indigo carmine in 5N sulphuric acid and 10 ml. of conc. sulphuric acid and heating to boiling. In the presence of nitrates, bleaching occurs ; ferric iron is removed by ammonia, using suction, while chromates are removed by means of barium chloride and ammonia. Heated with a nitrate, sulphuric acid evolves brown fumes of NO_2 on warming.

If a solution of nitrate (or nitrite) is shaken with mercury and an excess of conc. sulphuric acid, all the

nitrogen is set free as nitric oxide; the weight of the nitrate can be computed from the volume of nitric acid, using the nitrometer.

Gentle warming of nitrates with diphenylamine $(C_6H_5)_2NH$, dissolved in conc. sulphuric acid, produces a blue colour; in their higher valencies, chlorine, bromine, iodine, manganese, chromium, selenium and iron interfere.

No precipitate is formed with barium chloride or with silver nitrate. With ferrous sulphate solutions a brown zone is formed at the point of contact with a layer of conc. sulphuric acid. Irridium salts are coloured blue by nitric acid but not by nitrous acid.

A delicate test is afforded by brucine, which when dissolved in conc. sulphuric acid, gives an orange to pink colour in the presence of nitrates.

Another simple test is to heat with conc. sulphuric acid, to warm, and then to add copper turnings; the formation of brown fumes of nitrogen peroxide indicates the presence of nitrates.

By virtue of their easy nitration, many phenols serve for detection or determination; most sensitive are phloroglucinol and 1.3.4. Xylenol which give intense yellow colorations on making alkaline with sodium hydroxide.

Similarly, phenolsulphonic acid, added to extremely dilute solutions of nitrates produces a reddish or yellow tint, proportional to the content, on rendering ammoniacal; chlorides, which interfere, are removed by means of silver sulphate.

Nitrous Acid: Nitrites

Glacial acetic acid, added to a nitrite in an inclined test tube containing ferrous sulphate solution produces a brown ring; nitrates do not so react. If potassium iodide is present in the solution, free iodine is liberated.

Nitrous acid reduces potassium permanganate; nitrites may be added to a dilute sulphuric acid solution of the permanganate at about 40° C. followed by back titration with $F_eAm_2(SO_4)_2$.

Devarda's alloy is suitable for the estimation of nitrites by reduction to ammonia.

A comparative test consists in treating 25 m.. of the solution with 1 ml. of 5N. sulphuric acid and 1 ml. of a 0·25% solution of *m*-phenylenediamine sulphate, which produces a yellow to brown colour; nitrates and chlorides do not interfere.

A spot test consists in spotting a piece of filter paper successively with a drop each of alcoholic solution of sulphanilic acid, dilute acetic acid, the test solution, and dilute sulphuric acid and tracing around the spot formed with α—napthylamine; a brown colour indicates nitrite.

When an acetic acid solution of sulphanilic acid and α-dimethyl-amino-naphthalene is acted upon by nitrous acid a red coloration is produced, suitable for comparison, after 10 minutes, with identically treated standards.

Staff Changes and Appointments

Mr. E. Ineson, B.Sc., A.I.M. has resigned his position as chief research metallurgist of Messrs. David Brown and Son (Huddersfield), Ltd., to take up an appointment in the Metallurgy (General) Division of the British Iron and Steel Research Association at 11, Park Lane, London, W. 1. We understand that his new duties will be connected with the investigation of properties and applications of carbon and alloy steels.

Mr. A. T. Green, O.B.E., Director of Research of the British Refractories Research Association has been appointed to the office of Hon. General Secretary of the British Ceramic Society, in succession to the late Dr. J. W. Mellor.

Mr. Guy Harris, of Bullers, Ltd., Stoke-on-Trent, has been elected President of the British Ceramic Society for the year 1947–48.

Mr. Harry H. Ascough, A.M.I.Mech.E. has been appointed assistant work's manager of the Port Talbot and Margam plants of the Steel Company of Wales. He has been with Dorman Long and Co., Ltd. for 20 years, the last four of which as steelworks manager at that Company's Redcar Works and the five years before that as assistant to the general works' manager at Redcar.

Mr. W. V. Hodgson, latterly manager of the London Office of A. C. Wickman, Ltd., is now transferred to Coventry to take up an executive sales appointment for the Company; Mr. F. Ellis assuming the position of acting manager of the London Office. Mr. Allan Smith, on his return from an extended tour of the United States, is taking charge of the Company's Newcastle Office under Mr. J. Macgregor of their London Office.

Sir William Griffiths, D.Sc., chairman and managing director of the Mond Nickel Co., Ltd., has been appointed a member of the Advisory Council for Scientific and Industrial Research. Sir Andrew McCance, managing director of Colvilles, Ltd., has now retired from the Advisory Council on completion of his term of office.

Mr. L. H. Downs, managing director of Rose, Downs and Thompson, Ltd., has been appointed a director of the Power Gas Corporation, Ltd., and of Ashmore, Benson, Pease and Co., Ltd.

Mr. D. K. Coutts has resigned his position in the service of the Government of India as metallurgist under the Inspectorate of Metal and Steel, Ishapore, Bengal, to take up an appointment as chief foundry metallurgist at the Kulti Works of the Indian Iron and Steel Company in Bengal, India.

Mr. Gerald Steel has been appointed Joint Managing Director of the United Steel Companies, Ltd., with the Chairman, Sir Walter Benton Jones, Bt.

Mr. H. H. Mardon, B.Sc.(Eng.), M.I.C.E. A.M.I.Mech.E., M.I.Struct.E., M.Am.S.C.E., superintendent of the Plant Engineering Division of the British Iron and Steel Research Association has been transferred to the class of Member (M.I.Mech.E.) of the Institution of Mechanical Engineers.

Mr. D. W. Plaistowe, B.A., A.M.I.Mech.E., has been appointed to the board of directors of The Glacier Metal Co., Ltd., as commercial director. He was formerly commercial manager.

Mr. T. F. Pearson, M.Sc., has resigned his position with Colvilles, Ltd., and is now with the Consett Iron Co., Ltd., Co. Durham.

Mr. A. V. Nicolle has been appointed a director of the Sheepbridge Coal and Iron Co., Ltd., in place of the late Sir Henry K. Stephenson.

Mr. James Amour, cold rolling strip mill manager of Firth-Vickers Stainless Steels, Ltd., has been appointed a special director of the company.

Mr. A. L. Carr, B.Sc., has resigned his position at University College, Cardiff, to take up an appointment with the Research and Development Department of The Mond Nickel Co., Ltd., Wiggin Street, Birmingham.

Mr. M. K. Haldar, M.Sc., has resigned his position at the Research Department of the London, Midland and Scottish Railway Company, Derby, and is taking a special course in industrial and engineering radiography, held under the auspices of Kodak, Ltd., Harrow.

Mr. John C. Hannam has taken up an appointment as Research Assistant in the Chemistry Department of the British Iron and Steel Research Association.

Dr. L. Northcott has been appointed Superintendent of Research, Armament Research Department, Ministry of Supply, Woolwich.

Mr. N. G. Wright, B.Sc., has resigned his position with the Manganese Bronze and Brass Co., Ltd., Birkenhead, to take up an appointment with Roan Antelope Copper Mines, Ltd., P.O. Luanshya, Northern Rhodesia.

Mr. T. B. Horwood has resigned from the staff of the Metallurgy Division of the National Physical Laboratory, and has taken up an appointment with the British Iron and Steel Research Association.

Mr. R. Pearce, B.A., has taken up a position in the Research Laboratories of the British Aluminium Co., Ltd., Chalfont Park, Gerrard's Cross, Bucks.

Mr. J. Walker, B.Sc., A.R.S.M., has been appointed to the board of directors of the Morgan Crucible Co., Ltd., London.

Mr. J. A. Mannifield has been appointed chief works engineer to the Millom and Askham Haematite Iron Co., Ltd., Cumberland.

Mr. W. H. Goodlad has been promoted to assistant chief engineer in charge of flat rolling-mill design, and Mr. J. G. Frith to assistant chief engineer in charge of the design of hydraulic machinery, at Messrs. Davy and United Engineering Co., Ltd., Sheffield.

Personal

Mr. Brian Davidson, business manager and a director of Bristol Aeroplane Co. (Housing), Ltd., has been adopted as Unionist candidate for the division of Thornbury, near Bristol.

R. J. Fowler, B.Sc., D.I.C., A.C.G.I., 33, Woodthorne Road, Tettenhall, Wolverhampton, who in 1938 was co-author of a paper with Dr. A. H. Pandya, which received the 2nd Grand Award, has recently commenced practice as a consultant specialising in the application of welding processes to engineering design and production. He is an associate member of the Institution of Mechanical Engineers and of the Structural Engineers and has a wide experience of welding processes either in their application to design or in practice.

The Iron and Steel Institute

Autumn General Meeting

THE autumn meeting of the above Institute was held on November 12th to 13th, 1947, under the chairmanship of the President, Dr. C. H. Desch, F.R.S., at the Offices of the Institute. The first morning was occupied with the business of the Institute. After the minutes of the previous meeting had been taken as read, it was announced that the Council had nominated as President, to take office in May next, Sir Andrew McCance, D.Sc., F.R.S., who joined the Institute in 1914, and became a Member of Council in 1932 and a Vice-President in 1941. He is Chairman of the British Iron and Steel Research Association and has been very closely associated with the work of this Institute.

Changes in Council

The President reported that the Council have nominated Mr. W. J. Dawson, Vice-President, an Honorary Vice-President, in recognition of his long and distinguished service to the Institute. They have nominated Mr. James Sinclair Kerr, O.St.J., F.I.M., F.Inst.F., as a Vice-President. Further changes on the Council were reported by Mr. K. Headlam-Morley, the Secretary, as follows :—Mr. T. M. Service, to be an Honorary Member of Council in succession to the late Dr. J. W. Donaldson, during his period of office as President of the West of Scotland Iron and Steel Institute. Mr. W. M. Larke, M.A., to be an Honorary Member of Council in succession to Mr. C. B. Morrison, during his period of office as President of the Staffordshire Iron and Steel Institute. Mr. E. A. Davies, to be Honorary Member of Council in succession to Mr. G. J. Jones, during his period of office as President of the Swansea and District Metallurgical Society. The following Members are due to retire at the next annual general meeting and are eligible for re-election :—

Vice-Presidents : Mr. J. R. Menzies-Wilson, Mr. James Mitchell, and Mr. R. Mather.

Members of Council : Mr. I. F. L. Elliot, Mr. C. R. Wheeler, Mr. E. F. Law, Dr. C. Sykes, F.R.S., and Mr. D. A. Oliver.

Other Announcements

The annual general meeting, 1948, will be held in London on Wednesday and Thursday, May 5th and 6th, and instead of the dinner, which cannot be held under present conditions, there will be a conversazione on Wednesday, May 5th. The autumn general meeting will be held on Wednesday and Thursday, November 10th and 11th, 1948, in London. A blast furnace symposium will be held at the offices of the Institute on Wednesday and Thursday, May 26th and 27th, 1948. The Council are also considering holding a special summer meeting for members, and particularly for

Continental members, during the end of the first and during the second week of July, 1948.

Remarks by the President

On behalf of the Council, Dr. Desch welcomed all the members and visitors present, especially those from overseas. He referred with some satisfaction to the work of the year. In addition to the annual meeting in May, he spoke of the very successful summer meeting held in Switzerland in July, the arrangements for which were admirable. The symposium of Powder Metallurgy held in June was the first of its kind held in this country and proved very successful; indeed, it has been necessary to print a second edition of the Special Report in which the papers are published. Mention was also made of satisfactory meetings held in March and June; the first held jointly with the Institute of British Foundrymen and the British Iron and Steel Research Association, and the latter jointly with the British Iron and Steel Research Association to discuss some Corrosion Reports.

Referring to the educational side, Dr. Desch said that the scheme for National Certificates in Metallurgy had made rapid progress and expressed the Council's gratitude to Mr. H. S. Tasker for taking charge of this work as Chairman of the Joint Committee. The Joint Committee on Metallurgical Education has done a good deal of useful work, and is now considering a long-term programme under its new Chairman, Professor Leslie Aitchison, with a view to improving the standard of metallurgical education at all levels. The Mond Nickel Fellowships have not yet been awarded, but applications are being considered, and the first Fellowships will be announced soon. Applications for Carnegie Scholarships are still disappointingly few, evidence that conditions are still far from normal, and the opportunity was taken to remind research workers, especially those employed by iron and steel companies, and those working in the universities, that this fund exists and that the Council are prepared to make grants to suitable applicants.

TECHNICAL SESSIONS

The first two papers presented for joint discussion were those which had been discussed to some extent at the summer meeting held in Switzerland in July and reported in the August issue of this journal: these were, "Hydrogen and Transformation Characteristics in Steel," by Professor J. H. Andrew, Mr. H. Lee, Mr. H. K. Lloyd and Mr. N. Stephenson, and "Hydrogen in Steel Manufacture," by Dr. C. Sykes, Mr. H. H. Burton and Mr. C. C. Gegg. These two papers represent a very large amount of work undertaken by the Hair-Line Crack Sub-Committee. The next three papers presented and discussed jointly were: "Brittle Fracture in Mild Steel Plates," by Mr. W. Barr and Dr. Constance F. Tipper; "The Effect of the Manganese-Carbon Ratio on the Brittle Fracture of Mild Steel," by Mr. W. Barr and Mr. A. J. K. Honeyman; and "Some Factors Affecting the Notched-bar Impact Properties of Mild Steel," by Mr. W. Barr and Mr. A. J. K. Honeyman.

Hydrogen in Steel

Professor J. H. Andrew introduced the paper by his collaborators and himself. The main object of the extensive work described in this paper has been to establish the relation between hydrogen evolution and the transformation characteristics of steel. It has involved a comprehensive study of the evolution of hydrogen in steel, and results obtained for 22 different steels, hydrogen-soaked and cooled in vacuum under identical conditions, are reported. It is shown that in all cases relations between hydrogen evolution and transformation characteristics are marked and that there is a pronounced increase in the rate of evolution corresponding to the gamma-alpha change. The manner in which hydrogen is evolved from a steel is shown to be closely linked with the mode of transformation, but such a correlation does not necessarily determine the amount of hydrogen retained after cooling.

The authors consider that hydrogen embrittlement and hair-line cracks are closely associated with each other, and that hydrogen diffusivity and solubility are the controlling factors for both. The view previously expressed to explain hair-line-crack formation has been modified, in that the sudden evolution of hydrogen at the crack formation does not necessarily involve the breakdown of a hydrogen-rich constituent. Whilst hydrogen is the fundamental cause of hair-line cracks, stresses are important in that they may affect the diffusivity and solubility of hydrogen. Unless results of hydrogen diffusivity and solubility in steel for various conditions are available and the effect of structure and stresses upon them is thoroughly understood, controversies regarding the cause and mechanism of hair-line crack formation cannot be settled.

Mr. H. H. Burton presented the paper by Dr. Sykes, Mr. Gegg and himself, which he said was a companion to that by Professor Andrew and his colleagues, in the sense that it dealt with the industrial aspects of hydrogen in steel, rather than the laboratory study of the effect of hydrogen introduced into steel after its manufacture was completed.

Experiments on semi-finished products confirmed the results of previous work on steels artificially impregnated with hydrogen and indicated that ductility is reduced with hydrogen contents in excess of 2 c.c./100 g. Even when steel is melted under carefully controlled conditions, hydrogen contents of 4–6 c.c./100 g. are to be expected, which will adversely affect ductility if not removed. A study of the effects of various heat-treatments on hydrogen contents and susceptibility has shown that relatively high hydrogen contents do not automatically lead to hair-line cracks. No conclusive evidence was obtained on the question of segregation, although some alloy-steel ingots and forgings showed wide variations in hydrogen content.

Discussion

Mr. A. J. K. Honeyman thought these papers could be said to have solved the practical problems in relation to hydrogen in steel—the prevention of hair-line cracks, the effect of hydrogen on the mechanical properties, and the necessity of removing the hydrogen, or, where that cannot be done, preventing it as far as possible from getting into the steel. Continuing, he said, it was his personal view that hair-line cracks arose primarily from a transformation of minute quantities of residual austenite rich in hydrogen. Whether this resulted in hair-line cracking depended upon the amount of hydrogen and the mechanical properties of the matrix in which the residual austenite transforms. When the hydrogen content is high, cracking may occur in a soft matrix, whereas a higher matrix hardness may not result in hair line cracking provided the hydrogen content is low.

For example, the 3% nickel steel discussed by Dr. Sykes, pit cooled, with a low hydrogen, may under normal conditions not show hair-line cracks, but when the hydrogen content is high, as with the wild ingot, pit cooling is not sufficient to prevent hair-line cracks.

The only statement in Dr. Sykes's paper which shakes my belief in this theory is that which states high-chromium martensitic steels are not subject to hair-line cracks. He confessed to having no experience of such steels, and he sought more information on what that statement was based.

Dr. C. Sykes, referred to the paper by Professor Andrew and his colleagues and said the authors had introduced certain new ideas over and above those which were contained in their earlier papers. They now state that the rate of diffusion and the apparent solubility of hydrogen vary with the condition of the steel even in the α state. In other words, in any particular alloy steel, depending on the way in which it has been transformed, the rate of diffusion may vary and the apparent solubility can vary. Steelmakers want to know what is the condition into which the steel must be put in order to get the hydrogen out of it as quickly as possible.

They have introduced two further ideas which Dr. Sykes thinks are very interesting. One is that the hydrogen may segregate at the boundaries of the mosaic, and the second that the mosaic may form only at temperatures below, say, 250° C.

Mr. T. M. Service said in reading these papers the thought occurred to him that anybody, who has been in the steel trade for any length of time knows that at one time nitrogen was blamed for all the ills in steel, and then Sir Andrew McCance stated that non-metallic inclusions were to blame, and, I believe, Professor Andrew wrote a paper in which he showed that if we kept the phosphorus very low we got excellent steel.

Dr. S. A. Main on behalf of Mr. Colbeck, who was unable to be present, raised some points. His first was that he was quite sure that hydrogen is definitely a factor in the production of hair-line cracks. He thought there was a need for a standard test of susceptibility. Such a test would help to determine the incidence of hydrogen on the occurrence of flaws, and also the effect of the different factors in steelmaking.

Dr. W. J. Wrazej considered that Dr. Sykes and his colleagues, in their discussion of the subject, say, in effect : the reason why hydrogen is associated with cracking in ferritic, but not in austenitic and high-chromium martensitic steels is a mystery. It might be argued in the case of austenitic steels, they say, that they are very ductile and do not transform on cooling, but such arguments do not apply in the case of the high-chromium martensitic steels which, in addition, usually have hydrogen concentrations abnormally high compared with ferritic steels. The explanation of this anomaly might well throw useful light on the general hair-line crack problem. He thought there were not many such frank statements to be found in the published papers which must be so respectfully treated as this. He then described a way of interpreting the nature of austenite and martensite.

Mr. H. H. Burton, in his comments on the paper by Professor Andrew and his colleagues, was surprised to find at the end of the paper that the authors had come to the conclusion that the hydrogen pressure theory must account for the cause of hair-line cracks, because it seems that their evidence fits in just as well, if not better, with the idea that hydrogen embrittlement combined with stresses due to various causes such as transformation, segregation and so on are the cause.

Mr. D. A. Oliver felt that to some extent the discussion in the paper by Professor Andrew and his colleagues did not do justice to the factual character of the earlier part of it. He had been impressed by the ideas put forward in their previous papers and felt reluctant now to go into violent reverse. He did not think that in demolishing some of his earlier work he had quite done justice to all the considerations. He felt, therefore, that a critical summary from Sheffield University of what they really believe, would be interesting.

Dr. H. Lee replied to the discussion on the paper by Professor Andrew, Mr. Lloyd, Mr. Stephenson and himself, while Dr. C. Sykes replied to the discussion on the paper by Mr. Burton, Mr. Gegg and himself.

Brittle Fracture in Mild Steel

Mr. H. Barr presented for discussion the three papers on the above subject. In the course of doing so, he said : Brittle fracture came into prominence during the recent war with the application of welding on a wholesale, mass-production scale in America for the production of merchant shipping. Arising out of the several spectacular failures which occurred, a great deal of work was put in hand in America, and one might have thought from some of the articles in the technical press that brittle fracture in mild steel was a novelty. That, of course, is not so ; it has been known in mild steel ever since that material replaced wrought iron.

In this country the failures were more or less isolated, and on nothing like the same scale as in America ; it was simply a question of one or two isolated cracks. Nevertheless, the Admiralty Ship Welding Committee thought it worth while to initiate investigations in this country. The great bulk of the work was carried out by Dr. Tipper, under the direction of Professor Baker, in the Engineering Laboratories at Cambridge.

In October, 1945, a Conference was held in Cambridge at which a number of papers were read and discussed, dealing with both the practical and the theoretical aspects of the problem. That Conference was held under the auspices of B.I.S.R.A., the Admiralty Ship Welding Committee, and the British Welding Research Association. A month later, in November, 1945, B.I.S.R.A. asked me to form a small committee or panel to continue these investigations. I suppose that I was asked to undertake this work because I had contributed in a minor way to the Cambridge Conference, and I happened to be a member of the Metallurgy Panel of B.I.S.R.A. The other members of the team were : Dr. Tipper, of Cambridge, Dr. Allen, of the National Physical Laboratory, and Dr. Orowan, of Cambridge, and later we were joined by Dr. Slater, of the Admiralty.

Our work was influenced largely by the outcome of the Cambridge Conference. In the first place, it appeared to us to be very desirable to clarify the position with regard to the method of test used in assessing the susceptibility of mild steel to brittle fracture, and that is the subject of the first report, by Barr and Tipper, which deals with this aspect of the subject.

Mr. Barr then summarised the contents of the three papers.

Quoting for Aluminium Alloy Castings

By E. Carrington, M.Sc.

At one time it was customary for many foundries to quote for castings on weight alone, especially is this true of iron castings. Such a method of quoting was absurd and the past decade has brought about a revolution in which quotations for castings are based on a costing system, which permits a more reliable estimation of the cost of producing one or a number of castings to a given design. A method for arriving at the cost of producing aluminium alloy castings is described which facilitates quoting on an equitable basis.

IN many factories and stores, "quotation" simply means telling the customer how much the articles he has enquired about will cost, and when they will be delivered. Ultimately, this will also be the case with aluminium castings, but before the quotation is sent out many details should be considered; in fact, all details of the production of the pattern or die, and of the casting itself should be gone into thoroughly, as these affect the price and may also affect the speed of production of other jobs.

Sometimes the enquiry is in connection with a repeat order, and while in this case the quotation is comparatively simple, because it can be based on actual experience, it is worth while to take the opportunity of reviewing the position in order to see if the method of production can be improved or cheapened. For example, experience may have shown that an alteration to the die or pattern. or a different method of moulding might possibly speed up production and hence cheapen the casting. Sometimes a casting is giving more scrap than it should, and the majority of scrappers are from one particular cause. Modification of production methods to remove this cause would be an economy.

When quotations are being considered, all departments which can help should be consulted. With repeat quotations, no doubt the foundry itself, the pattern shop, the laboratory, the machine shop (if a die is being considered), the costing department, and the progress department would all give useful information. If statistical control is being used it would probably give valuable assistance.

New quotations should be considered carefully in all details and as much information as possible should be obtained from the customer. It may sometimes be thought that this close enquiry into the customer's business is rather bad manners and in any case is hardly necessary, but it must be remembered that any individual item may have an important bearing on the quotation. For instance, it may be necessary to choose a special alloy which machines well or has good corrosion resistance. Again, the information obtained may enable the foundry to make helpful suggestions as to the slight alteration of the casting in order to cheapen the production, or to advise the making of die castings instead of sand castings, or pressure castings instead of gravity castings. Careful consideration of all these points in close collaboration with the customer, will give him confidence in the foundry and will build up that friendly spirit which is so essential in all branches of industry.

The items which affect the price of the casting are perhaps more numerous than might at first be supposed. Let us consider some of them.

1. How many castings are required? If at all possible, information should be obtained as to whether there will be a repeat order, as the total number required may have an appreciable effect upon the price. If the present enquiry represents only a small part of what will be a running order, it may be worth while to change from sand castings to die castings, but if nothing is said at the enquiry stage about repeat orders, sand castings will be quoted for, and when repeat orders come, the customer will either have to continue having sand castings made, or will have to incur extra expenditure on a die which could have been ordered in the first place. Even if sand castings are to be made, the question arises as to whether the job should be speeded up by making several patterns, by putting several patterns in one box, or by machine moulding. The quality, and therefore the cost, of the pattern has also to be considered. If only a few castings are required, and there will be no repeat order, a cheap pattern may be used which will produce the required number of castings without undue wear, and will not add much to the cost of the castings. On the other hand, if repeat orders are contemplated, a first class mahogany pattern will be required, and if the number is to be very large, a metal pattern will be worth while.

The number of castings required for one particular order will influence the price in another way. If long runs can be made, frequent changes of patterns, with accompanying waste of time, and increase of overhead costs is avoided, and hence a slightly lower price can be quoted.

When die castings are ordered, the quantities required may govern the method used. If only a comparatively small number are required, it may not be considered economical to make pressure dies from expensive alloy steels—gravity dies would therefore be made. If gravity castings were ordered it might be necessary to consider whether to provide a many part core or to make sand cores. Many part cores are expensive, and if the order does not enable them to be used to the end of their useful life, it will probably be more economical to make a core box and to use sand cores.

2. What alloy is to be used? It may be that this has been left to the foundry to decide. On the other hand, an alloy may have been asked for which is unsuitable for the job. For instance, some alloys which are quite useful for the production of sand castings cannot be used for die castings. Only a few are suitable for pressure castings. As pressure castings do not lend themselves to heat treatment, it is not worth while to use a comparatively expensive heat-treatable alloy for pressure castings when the advantages of heat treatments cannot be obtained.

There is a wide range of aluminium foundry alloys, which differ from each other in physical properties, foundry properties, and of course, price.

The high strength alloys are given their optimum qualities by heat treatment. Some of them present some difficulty in the foundry and more so in the die shop, and for at least one of them a special foundry technique has been developed, which will add to the cost of the castings and will have to be considered when quoting. With some of them it is essential that they shall not be adulterated to the slightest degree if the specified physical properties are to be attained. If therefore, full laboratory control is not available it would probably be better not to use these alloys.

There are other high strength casting alloys with better castability than those mentioned above and with less tendency to deteriorate when slightly adulterated.

There is a range of medium strength alloys, most of which are heat treatable. Most of them contain a number of added metals, and hence a little adulteration would not mean the scrapping of the castings or the use of the metal to make poorer quality alloys which would sell at a lower price than the unadulterated alloy. This does not mean of course, that any less care should be taken to control melting conditions or the segregation of scrap. These alloys are generally more castable than the high strength alloys and some of them require only one heat treatment.

There are other alloys which do not require heat treatment but which have not quite the strength of the heat treatable alloys. Most of them are the old-established alloys which have been to some extent, superseded by the more modern alloys. Some of these lower grade alloys are made from remelted foundry and machine shop scrap, and while at one time they would have been considered hardly worth using, modern melting practice as carried out in our reclamation foundries and the development of fluxes has enabled alloys to be produced of first-class quality which are used in very wide fields of application.

At the bottom of this quality scale is nondescript material, which may be ordered as "aluminium alloy," "Grade D," or simply as "alum." It consists of remelted foundry scrap which has not been adjusted in any way to conform to a definite specification. Obviously its main disadvantage is the variability of its composition from one delivery to another, and this will be accompanied by variations in foundry properties. Nevertheless, there are jobs, especially perhaps in the pressure foundry, where cheapness is the overriding point which decides whether or not aluminium alloys shall be used. In such cases "Grade D" would be considered.

The prices of these alloys vary a good deal and if friendly relations have been established with the customer, useful advice can often be given as to which alloy to select. The alloy asked for may be lacking in some important property and could perhaps be replaced by a more suitable one, or possibly a cheaper alloy would be more castable. If possible, an alternative alloy should be asked for in case the first one gives trouble in the foundry. Alternatives are generally given on the drawing for aircraft castings.

3. For what purpose is the casting intended? Here again, the foundry may be able to give useful advice. If the operating conditions have been given by the customer it may be possible to advise him as to the best alloy for certain corrosive conditions, or if the castings are to be plated or anodised, the best alloy for such a purpose could be suggested. If high electrical conductivity were required it might be necessary to compromise between an alloy with the lowest possible addition of alloying elements and one with enough additions to make the castings in question easily castable.

4. Are the castings to be machined, and if so, where? While this is generally shown on the drawing, it is as well to make sure. The parts to be machined are usually put at the bottom of the mould in order to obtain maximum soundness. If a first class machined surface is of primary importance, it may be necessary to mould the casting in an unorthodox way. For instance, it may be considered necessary to use a hanging core, when the casting could be cast the other way up without a hanging core. All this must be considered at the quotation stage as it has a definite bearing on the cost.

5. Are the castings to be subjected to Air Ministry or similar inspection? If they are, it is necessary to carry out chemical, physical and radiographic tests. These will increase the cost of the castings and may also delay the delivery. The alloy and the casting will have to comply with the relevant D.T.D. or B.S.S. specification and with the drawing.

6. If the customer simply asks for castings, without specifying the alloy, it will be necessary to study the drawing and to consider which alloy should be recommended. It will also be necessary to give advice as to whether the castings should be sand, gravity, or pressure cast. It may be that the wrong kind of casting is being asked for. For instance, large castings, or those with thick sections do not lend themselves to casting by the pressure process. If the casting is of complicated shape and quick deliveries are required, die castings will be out of the question. There are many other points which may have to be considered when the choice of alloy and casting process is left to the foundry in this way.

7. Could the casting be improved, and/or cheapened? It is sometimes possible to show the customer that a slight alteration to the casting would enable it to be made more easily and therefore more cheaply, or would enable it to be made as a die casting instead of a sand casting. If fixing lugs or bosses are placed on the inside of a hollow casting it would probably be necessary to make a complicated and costly core if the job were to be die cast. If however, the lugs were put on the outside of the casting, a simple one-piece core could be made.

If part of the casting consists of a curved pipe, the designer may have made it of such a shape as would present difficulty to the founder. If the job were to be die cast, it might be impossible to withdraw the cores which would form the inside of such a pipe. Slight alterations to the curvature and the taper, if any, would considerably ease matters and would enable the job to be die cast without difficulty. When castings have widely differing sections it may be possible to make the thick sections thinner and to strengthen them by the addition of webs. If wording is required on a pressure casting and this is shown sunk in the casting the customer should be informed that it would be much cheaper to cut the wording in the die, giving raised letters on the casting, than to cut away a good deal of

expensive die steel to leave raised letters on the die, giving sunk letters on the casting.

8. Is the order wanted in the foundry? This may at first be thought to be rather a ridiculous question, which if asked at all should have been asked at a much earlier stage. There must be some cases however, when the foundry would rather not have the job, and when this is not known until it has been fully considered. Suppose for instance, that it is a job which requires machine moulding. It may be that the kind of machines which would be used for it will be fully occupied for some time. In such a case it would be fairer to the customer to let another foundry make it. Again, if it is found that the alloy required is one which is not used by the foundry, and which may at first cause trouble, it may be considered unwise to experiment with a new alloy for one order. The casting may require machining, but the foundry will not be equipped for machining all the castings which it produces. If then the machines are all occupied to capacity, it will not be possible to accept an order for castings which require machining. Similarly, with heat treatment: a number of different alloys with different heat treatment times and temperatures may be in use, and it may not be possible for the heat treatment furnaces to take any more castings in certain alloys. It may, therefore, be necessary to give preference to non-heat-treatable castings or to those for which room can be found in the heat treatment furnaces.

Some jobs are particularly difficult, either because of their complicated shape or because of the poor foundry properties of the alloy. Admittedly, the acceptance of a few such jobs adds interest and gives useful experience in the foundry, but the acceptance of too many of them is neither economical nor good policy. The foundryman has to give close attention to them for a long time, and is therefore unable to give sufficient attention to each one if they are too numerous. He is likely to lose interest and the object of accepting such orders—the widening of experience—would be defeated. Careful consideration should be given to these difficult jobs and the foundry manager should take only a limited number.

When the above points (and probably others in special cases) have been considered, it is possible to come to a decision as to how the casting is to be made. If facilities are available, it is a good policy to make a rough drawing of the casting with the runners, risers and chills shown. For sand castings the runners and risers should be sufficiently large and sufficiently numerous to make reasonably sure that the casting will be sound, and when the job goes into production it may be possible to modify them in order to cheapen the castings by lessening the moulding time and the weight of metal required.

In the case of gravity die castings the die would be designed with the smallest possible risers, and if necessary these would be increased by further machining of the die.

When the method of manufacture has been decided upon, the cost of producing the pattern or die, and then that of the casting may be estimated.

There are quite a number of points connected with the actual methods of production, which have to be considered in detail before a decision can be arrived at, and this appears to complicate matters, but there is an outstanding compensation in the fact that aluminium castings may be made in three kinds of moulds, namely, sand moulds, and gravity or pressure dies. The importance of this adaptability cannot be over-stressed, especially when it is remembered that some aluminium alloys can be cast by all three processes. This enables a customer to order a few castings, modify them until he is sure as to what he wants, and then to order increasing quantities. In the first place, he may perhaps machine parts from rolled or extruded bar, and fit several together. After a few alterations and trials he can have the composite part made as quite a rough casting. This would be made in small quantities using a cheap pattern with a fair amount of machining allowance. The customer could then try these and make any further modifications which he found necessary. He could then order a larger quantity of sand castings, made from a good mahogany or metal pattern, and while these were being delivered he could have a gravity die made. If the casting were of suitable form he might still further increase the rate of production by ordering pressure castings. In this way he could adopt, adapt and improve while production was proceeding, and the foundry could help him very materially. This kind of development work was carried out on a large scale during the war, when aircraft manufacturers had to change over from wrought parts to high-strength castings.

Quotation for Castings

The various items necessary to provide the data for a quotation should be entered on a quotation sheet, which should be filed when completed, so that the actual cost of the job may be compared with the estimated cost. In this way, the foundry will notice any errors which may occur in the estimates, and will correct them for future quotations, thus obtaining an increased accuracy in the quotations. It is, however, important that each new enquiry should be considered independently. There is sometimes a tendency to say that a new job is very similar to that one received six months ago and to simply copy the quotation details. An extra boss, a flange, or a local thickening might make a radical difference to the method of running and hence to the price.

A suggested quotation sheet is given on the next page. Individual foundries would probably find that some modification was necessary.

Under the first heading—metal required—is placed all the metal which is actually melted for the casting, including runners, risers, spillings, etc. For most aluminium alloy castings the runners and risers weigh approximately the same as the casting. The figure given under this heading will therefore be twice that given above as the weight of the casting. The casting weight will either be obtained from the customer, or by finding the volume of the casting from the drawing and allowing 0·1 lb. per cubic inch as the weight of the metal, or if a pattern is supplied, by weighing the pattern and calculating the weight of the casting from the relative densities of the pattern material and the metal to be used for the casting.

Under the scrap heading is entered the difference between the weight of the metal melted and that used in the casting. As before mentioned, this will be half the weight of the melt. Experience with different alloys will probably show that this proportion should be modified, but the extent of the change is not likely to be great.

QUOTATION SHEET.

ALUMINIUM ALLOY CASTINGS QUOTATION.

NAME..... DATE.....
Die or Part No.....Dwg. No.....
Alloy..... Weight..... Spec.....
Quantity.....

	£	s.	d.
METAL: .... lbs. at .... per lb.			
Less .... lb. scrap at .... per lb.			
Heat treatment at .... per lb.			
+ .... per lb.			
LABOUR: Moulding			
Coremaking			
Rough fettling			
Dressing			
+ .... % bonus			
+ .... % W.E.			
Inspection and rejects %			
Total cost			
Cost per lb.			

Polishing.....Quoted by.....
Machinery .....Quoted by.....

	£	s.	d.
DIE or PATTERN: Material			
Total material cost			
Labour			
+ .... % bonus			
+ .... % W.E.			
Total			

Die or Pattern.....Quoted by.....
Delivery .....

The value which can be given to the scrap will depend to some extent upon the kind of casting which is being made. If the alloy used is low in the quality scale and high strength is not asked for, and if the melting technique is satisfactory, the scrap could be remelted for the production of similar castings, and may be valued at its original price, but if high quality castings are being made, it may be considered necessary to use the scrap for somewhat cheaper castings, and its value will therefore have deteriorated. This applies specially to alloys used for die-castings, where there will be some iron pick up which may put the iron content of the scrap outside the specified range. The scrap value should be estimated carefully, so that its deterioration in value is put against the cost of the current job.

The cost of heat treatment varies a good deal with various alloys. Some require only a high temperature treatment at about 520° C., others only a low temperature treatment at about 150° C., and others require both. There is also a considerable variation in the times of these treatments. Individual foundries will no doubt treat this item in their own way. For example, some may obtain the cost per hour for the various treatments and use the one which applies, for the alloy being treated. Others may decide upon an overall charge for the high, low, and double treatment, and charge all castings which are treated in one particular way the same amount.

The item " + ... per lb." is intended to cover the cost of melting the metal, and handling the castings in the foundry. It will depend upon the cost of fuel and power, and on labour charges, and will be found by experience.

The moulding cost may be determined on a basis of the volume of sand rammed per hour by the method being used. An average figure can be found for each method of moulding and as the volume of the box and that of the casting are known, it is possible to calculate the number of boxes which will be rammed per hour. From this the moulding cost per casting or per 100 castings may be obtained. To this it will be necessary to add a coreing cost which will depend upon the number and intricacy of the cores.

In the die shop, the speed of working when the die has attained the temperature conditions which give sound castings can be estimated from previous experience.

By " rough fettling " is meant the removal of the runners and risers by means of band saws or chippers.

" Dressing " refers to the final fettling of the castings after they have had the runners and risers removed. In aluminium foundries, these processes are generally carried out by different men. The prices are, therefore, kept separate for convenience.

" Bonus " will include cost of living bonus and any other bonus which may have been agreed upon by the management and the men's representatives.

The amount of overheads will depend upon the proportion of indirect labour, rates, taxes, maintenance costs, etc., and will in the first place be estimated by the cost department. Later they will be based upon actual experience and will be modified from time to time as conditions alter.

The amount to be allowed for inspection and rejects will vary widely and will depend upon the method of casting and the number required. In the case of die castings the scrap should be quite small because of the uniformity of casting conditions. On the other hand, in the case of a sand casting of complicated shape, where the order is for only two or three, there is quite an appreciable chance of something going wrong with the first one, and this means quite a high " reject " figure. This possibility should be faced and allowed for. It is much better to charge more for the job and possibly lose it, than to charge less and work at a loss. If repeat orders are received later, the reject figure can, of course, be altered and a new price quoted. An alternative method would be to charge a low rejection percentage and allow for the possible higher figure in the " development " account.

It will be seen that space is provided on the form for cost per casting and cost per pound, and while both could be entered, most foundrymen are of the opinion that only the cost per casting should be quoted. Admittedly the customer sometimes asks for the cost per pound and will sometimes compare the cost per pound of one casting with that of another, and ask why there is such a difference. The difference is due, of course, to the moulding, fettling and coreing charges, and the skill required in making a good casting from a complicated pattern. To the customer who thinks that all castings in the same alloy should be charged the same price per pound, it might be pointed out that there are cases where a casting can be altered slightly to improve the running, and that although this may increase the weight the price can be lowered because of easier moulding.

It is difficult to see why anything other than the cost of the casting is required. The customer who is building an aircraft, washing machine or other built-up article wishes to arrive at a price which he can charge for the finished article. Surely the only figures which can help him are the costs of each component, and the cost per pound will not have a bearing on the final cost of the assembled component. With aircraft, of course, the weight is important, but that will have been gone into fully when the machine was designed.

The cost of machining, polishing, or any other finishing process can be obtained from the department concerned, or if the work is done outside, quotations may be obtained, which should be entered on the sheet for future reference.

Quotation for Pattern or Die

Under " material," particulars of the material required are entered, including quantity, shape and kind, such as mahogany, alloy steel of definite composition, etc.

The tool room and pattern shop overheads will differ considerably from those of the foundry. They should, therefore, be kept separate and should be applied only to patterns or dies. As is the case with finishing charges, outside quotations for patterns or dies should be entered on the quotation sheet for ready reference.

Delivery

The subject of quotation cannot be left without some reference being made to the question of delivery. Many foundrymen will no doubt agree that more annoyance is caused amongst customers by late delivery than by all other causes. It is, of course, natural that a foundry should try to give a delivery date which is earlier than its competitors', but customers are far more interested in the actual delivery than in the promises. If the machine shop has been prepared for machining the castings on a certain date and they do not arrive, the loss to the customer may be quite appreciable.

Take two examples. Suppose that in one case delivery is promised on the 7th and takes place on the 8th, and that in the other it is promised on the 9th and takes place on the 8th. In both cases the delivery is on the same date, but what a difference in the feelings of the customer.

When considering the delivery date, full consideration should be given to the other jobs which are running through the foundry. The moulding machine on which the new casting is to be made may be working to capacity. Again, if there are a number of alloys which require heat treatment, a good deal of ingenuity is required to fit them in, and this may cause some delay. Such details should be given full consideration and all the production departments should be given some latitude.

There are, of course, some cases where this does not apply. If castings are required for the prototype of a new aircraft, it is of the utmost importance that it should be delivered in good time, and every effort must be made to that end. This sort of job is, however, a special one, and is not generally quoted for in the usual way.

British Welding Research Association Director Meets Representatives of Member Firms

Dr. H. G. Taylor has taken up his duties as Director of Research of British Welding Research Association and an early opportunity was made for him to meet the representatives of the firms who are members of the Association. Such a meeting was held on November 18th at the offices of the Association, 29, Park Crescent, London, W. 1. The meeting was opened by the President of the Association, Sir William J. Larke, K.B.E., who briefly described the circumstances which led the Council to make a change in the policy of the Association and with Dr. Taylor as Director they look forward with confidence to the progressive development of the work of the Association along lines which will ensure control of the programmes within the limits of the financial resources available.

In his address to the representatives Dr. Taylor said it is difficult to co-operate with a firm unless there is a representative who acts as a channel through whom all dealings take place. Such an approach has its dangers as well as advantages. The nominee may act as the interpreter of the Association to his firm, but he should be able to speak the language of both. He expressed the hope that each representative would have an appreciation of what the Association is trying to do and would make that clear to his own organisation —seeing that the results, in the right form, go to the right people. He was also anxious that each should effectively convey the hopes and wishes of his particular firm: their needs and problems; the difficulties they encounter and the ways in which the Association could help.

Member firms naturally want to get value for what they put into the Research Association. The Association too is anxious that they should get good value, but however intrinsically valuable the work may be, it is only of *potential* value to industry; it can only be converted into *real* value when it is applied in practice by member firms.

In concluding his address Dr. Taylor said: " Our policy will be one of helping and encouraging research in the large field of welding wherever and whenever possible. We have already plenty of work to do for the funds available, and there will be no ' dog-in-the-manger ' spirit. If we can do anything to help members to get a valuable piece of research going, we shall do so—believing that our primary concern is the good of all industries associated with welding. We shall grow and prosper as the practice of welding grows and prospers, and we shall openly and frankly give help and encouragement wherever we can, and I have no doubt we shall receive like treatment in return.

" I hope we shall build up a first-class scientific institution which will justify your confidence in our ability and our integrity. Your confidence in us is essential, and I believe that the personal relationship which I have advocated, will be the first step towards establishing this. We want to turn out work of first-class quality which will redound to the credit of the Association, the credit of the industry and the credit of our country, and in order that the responsibility for this may be equitably shared, I hope you will, individually, put in a good word for the Association wherever you can. Talk us up, not down—and let us spread our membership until all firms in the country doing welding share the costs and share the benefits."

Change of Address of Non-Ferrous Metals Directorate (Disposals)

The Ministry of Supply announces that the address of the Non-Ferrous Directorate is now 2, Hyde Park Street, London, W. 2, instead of 31–43, Norfolk Square, London, W. 2. The new telephone number will be Ambassador 1290. The Telegraphic Address remains, Metrol, Padd, London.

The Effect of Notching on Materials of Construction under Static and Dynamic Tension*

(Maximum Testing Velocity 29 feet/second)

By Dr. Georges Welter,

Professor of Applied Mechanics, Ecole Polytechnique, Montreal.

This report discusses the results of static and dynamic tests performed in order to determine the effect of notches in specimens of various construction materials. The maximum initial testing velocity used was about 29 ft. per sec.

The properties of some light alloys and other structural materials were measured by comparing impact loading with static loading force-elongation diagrams recorded on a specially designed device. A tangential dynamometer with a spiral spring adjusted between steel strips records the dynamic load while simultaneously the elongation of the specimen is recorded by the rotating movement of a drum in a perpendicular direction. The maximum dynamic load that can be recorded by this device is about 3,000 lbs.

The total energy, the elongation and the energy absorbed per unit volume, for six different materials, were measured on specimens tested at a rate of straining of 0·005 ft. per second and compared with the same values measured on identical specimens strained about 20,000 times faster. As the volume and not only the section of the specimen or the structural member absorbs the applied load, it seems that the strength calculated per unit volume is a more reliable value than the strength calculated per unit section.

These tests confirm the conclusions reached in a previous investigation, to the effect that the dynamic strength of cylindrical 2 in. gauge length specimens, at a speed of 11·78 ft. per second, is up to 60% higher than the static strength, depending on the material tested; in the case of zinc, it is 100% higher. At higher speeds, the ultimate strength is still increased. Furthermore, the notching effect under static and dynamic loads is very pronounced for all materials tested.

The dynamic as well as the static strength increases with decreasing gauge lengths, the amounts depending on the ductile properties of the material tested and the speed of the impact loads.

Notched specimens are very sensitive to impact loads at high speed, and even very ductile materials stand this test only in the annealed condition.

Most materials can be classified in three groups according to their behaviour under impact loads. The first group includes materials which are brittle at low impact speeds whether the specimen is cylindrical or notched. In the second group belong the materials whose strength and elongation increase with increasing speed when tested in the form of cylindrical specimens of at least ½ in. gauge length; however, these materials are very sensitive to the introduction of a notch in the specimens, which checks the flow of material. The third group comprises extremely tough materials (such as nickel-iron and nickel-copper alloys) which have the valuable property of flowing locally at the bottom of the notch even under high deformation speeds.

The ductile metals such as aluminium and zinc behave in a similar manner. The static strength increases with the sharpness of the notch and the dynamic strength of cylindrical specimens is higher than their static strength. With aluminium, a maximum load of 26,200 lb./sq. in. was recorded in the dynamic test, compared with 22,700 lb./sq. in. in the static test. Zinc in the form of cylindrical specimens showed a much higher resistance under dynamic than under static loads. Two specimens tested dynamically did not break under the highest load of 45,000 lb./sq. in. and the absorbed energy was over 170 ft.-lb. However, when tested in the form of sharp V- and U-notched specimens, this metal behaves like very brittle material since only 9–11 ft.-lb. were necessary to break these specimens (indicating a maximum load between 6,250 and 11,200 lb./sq. in.). With aluminium, the energy and the breaking load were small for sharp U-notched specimens.

2. *Results of static and dynamic tests on cylindrical specimens with V-notches of* 160° *and* 90° *and with sharp U-notches* (Fig. 18).—After tests on soft materials, a more elaborate series of tests were made on 16 various alloys (including different heat-treatments) using four different shapes of specimens; that is one 2-in. gauge length cylindrical specimen, one with a V notch of 160°, a third one with a 90° V notch, and a fourth with a sharp U notch of $\frac{1}{32}$ in. width. The diameter of the specimens varied, according to the strength of the material tested, between 0·15 in. and 0·23 in. The most significant results of this main series are plotted in Figs. 19 and 19a. Here, also, the results of the static tests on some of the specimens can be easily compared with the results of dynamic tests on specimens of the same type. The numerical values plotted on the diagram are those recorded by the special dynamometer designed for checking purposes and are not always in close agreement with the values used to determine the ordinates of the curves. It happened that the recording drum or the paper on the drum were somewhat shifted during the application of the impact load, as a result of the violence of the shock; this explains why the actual load had to be verified by means of the special dynamometer. The speed for these tests was, in most cases, 11·78 ft.-sec. but a few tests were carried out at a higher speed of 16·68 ft./sec. The diameter of the specimens varied between 0·225 in. for soft metals, such as zinc and aluminium, and 0·15 in. for stronger alloys.

The results obtained show that the dynamic strength of most materials tested in the form of standard cylindrical specimens, increases appreciably when the striking velocity is increased from practically zero ft./sec. (static test) to 11·78 and 16·68 ft./sec. (dynamic tests). The elongation also increases for most materials.

Thus, for instance, drawn aluminium (Fig. 19) shows in the form of a cylindrical specimen a static breaking strength of 910 lb., whereas its dynamic strength is from 1,300–1,450 lb. However, if a flat "V" notch of 160° is provided in the specimen, the static strength rises to 1,171 lb.; a similar specimen tested dynamically with a speed of 11·78 ft./sec. shows about the same

*Continued from page 343 October issue.

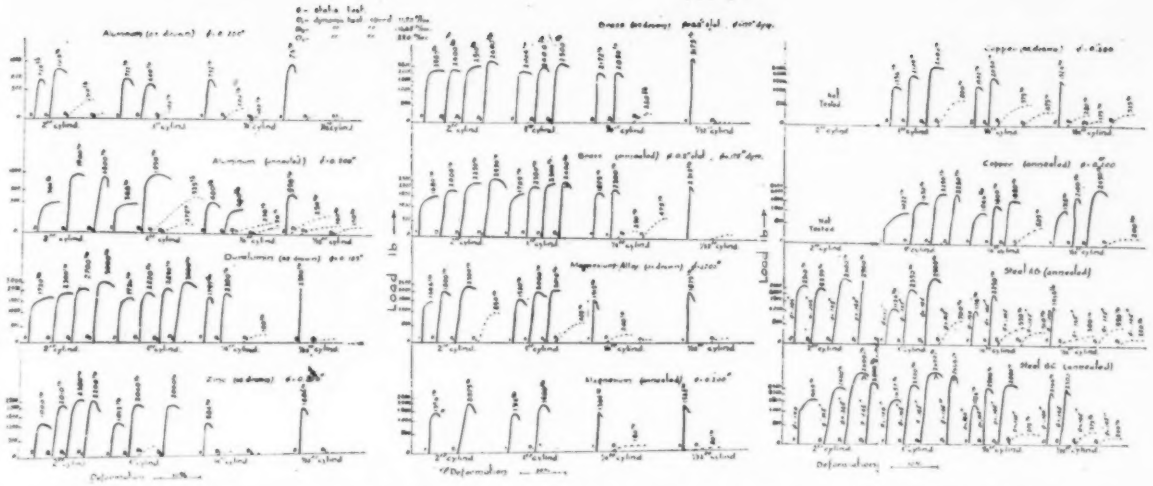


Fig. 21.—Records of static and dynamic tests on cylindrical specimens of various gauge length ($\frac{1}{32}$ in. to 2 in.) of structural materials under testing speeds of 0, 11.79, 16.68 and 29 ft./sec.)

resistance as when loaded statically. If higher speeds are used (16·68 ft./sec.) the resistance becomes much smaller and falls down to as little as 287 lb. The same effect can be observed by testing specimens with a "V" notch of 90°. The static load rises to 1,509 lb. while, on the other hand, the dynamic ultimate load falls down to 220 lb. with a speed of only 11·78 ft./sec. Similar results were obtained with specimens having a very sharp "U" notch of about $\frac{1}{32}$ in. width; a high static breaking load (1,418 lb.) and a very low dynamic load (180 lb.) were recorded. The energy necessary to fracture the specimens dynamically decreases gradually with the localisation of the flow of the material as the effective length of the specimen is decreased through the introduction of a "V" or "U" notch. It is surprising to find that this rather ductile material, which shows good static and dynamic strength when tested in the form of a cylindrical specimen, and equally good static strength in the form of a sharp-notched specimen, behaves, however, like a very brittle material when tested under dynamic load in this latter form.

With annealed aluminium, the difference between the static and the dynamic strength of cylindrical specimens is very pronounced, the ratio being more than 1 to 2. The introduction of a V notch in a cylindrical specimen increases its static strength, while the dynamic strength remains the same. Here, too, tested with the higher velocity of 16·68 ft./sec., the notched specimen breaks under surprisingly low loads of a few hundred pounds.

Aluminium alloy 17 ST, a less ductile material than pure aluminium, shows, in the form of cylindrical specimens an appreciable loss of its strength when tested at the high speed of 16·68 ft./sec. Only about 100 lb. were recorded, whereas a load about 10 times higher was reached at the lower speed of 11·78 ft./sec. On the other hand, this material seems to be rather sensitive to notches; the introduction of "V" notches of 160° or 90° and of a "U" notch increases the static strength as compared with the cylindrical specimens, whereas the dynamic strength, even with the small testing speed of 11·78 ft./sec., is reduced to very small values (Fig. 19).

Brass and magnesium alloys behave in a similar manner. Tests on cylindrical specimens of these materials show that they resist higher dynamic than static loads. Even a speed of 16·68 ft./sec. has no detrimental effect on these two alloys tested in the form of cylindrical specimens of 2-in. gauge length. These materials are also very sensitive to notches: under static loads their strength increases as compared with cylindrical specimens, but under dynamic loads with a speed of only 11·78 ft./sec., their resistance becomes practically nil (<100 lb.). Notched specimens of these materials can be broken with a sharp blow of an ordinary hammer weighing about 2 lb. (Fig. 19).

Cylindrical specimens of zinc have a very high strength ratio: 2·19 with a speed of 11·78 ft./sec., and 2·9 for a speed of 16·68 ft./sec., the highest value attained in this test series. It is remarkable that this material should have such a high dynamic resistance in the form of cylindrical specimens. The elongation (18·4–20%) and the reduction of area (65–67%) are much smaller than in the static test (35·8% elongation and 87% reduction of area) (Fig. 19).

The other materials such as armco iron, mild and medium steels, whether annealed or not, are similarly influenced by notches under static as well as under dynamic loads. As with the previous materials, the static strength increases with a decreasing effective volume under plastic flow (notched specimen), while only the cylindrical specimen of 2-in. gauge length shows a higher breaking strength under dynamic than under static load (Fig. 19). Even armco iron, which has a static to dynamic strength ratio of over 1·55 in the form of cylindrical specimen, shows, in the form of "V" or "U" notched specimens, a very low dynamic resistance. Mild and medium steels behave in a similar manner, with the exception that specimens with a V-notch of 160° show a dynamic resistance which approaches that of cylindrical specimens. Specimens with a 90° V notch and with a U notch present hardly any appreciable resistance.

Monel metal in the as-received condition behaved in a manner different from all the other materials tested in this series in so far as it showed practically no notch sensitivity. Apart from the fact that its static resistance increased by about 60% with the introduction of a sharp

V-notch in the specimen, and also that its static to dynamic strength ratio was 1·2, showing at the same time higher elongation and reduction of area than in the static test, the notched specimens did not break under the heaviest dynamic blow of the machine. Not only did the flat V-notched specimen resist a dynamic tension causing a stress of 132,000 lb./sq. in. at 11·78 ft./sec., but the sharp-U notched specimen itself did not break under the heaviest load of 2,200 lb. Only annealed aluminium stood this test, and all other materials failed under such conditions. These are the best results obtained in this series, showing that Monel metal is extremely tough and seems to remain practically unaffected, even by notches of various shapes so detrimental to most of the materials under dynamic loads.

A material, however, which is extremely sensitive to dynamic loads and which ranks lowest among low-resistant alloys, is grey cast iron. The introduction of a notch in the specimen does not cause any serious increase in resistance. When increasing the sharpness of the notch, the static resistance falls down to 764 lb. from 982 lb. for a cylindrical specimen; this material is practically without any dynamic resistance, as tests performed, whether on cylindrical or notched specimens, showed a breaking load practically nil (<50 lb.) and the energy absorbed by the specimens amounted to only a few ft.-lb. Cast iron is a typically brittle material without any ductility and cannot stand severe impact loads. It breaks without local deformation, much like glass or china.

3. *Results of tests on cylindrical and notched specimens of* 2 *in.*, 1 *in.*, $\frac{1}{4}$ *in. and* $\frac{1}{32}$ *in. gauge length with testing speeds of* 0, 11·78, 16·68 *and* 29 *ft./sec.*—As these results agree on the principal points with those of the foregoing series, they will not be discussed in detail. Fig. 20 illustrates the influence of the gauge length of the specimens on the static strength for seven materials. It will be seen that the ultimate strength does not vary very much between 2 in. and $\frac{1}{4}$ in. gauge length. For notched specimens with a gauge length of $\frac{1}{32}$ in., the static strength increases appreciably for all materials. Furthermore, the results illustrated in Fig. 21 differ from those of Fig. 20, only insofar as, in the former case, cylindrical specimens exclusively, with gauge lengths between 2 in. and $\frac{1}{32}$ in., were tested. The diameter of these specimens varied from 0·175–0·2 in. As it is difficult to evaluate the working volume of specimens with V notches, short cylindrical specimens of 1 in. and $\frac{1}{4}$ in. gauge length were substituted for them in this series. This accounts for the variation in the results, as tests on cylindrical specimens are less severe on materials than tests on V-notched specimens. Furthermore, having regard to the higher velocity of 29 ft./sec. and the increasing resistance of some materials, a stronger helicoidal loading spring had to be used in the apparatus, so that the curves recorded are plotted to a smaller scale than that of Fig. 19.

Drawn aluminium and annealed aluminium cylindrical specimens of 2-in. gauge length and of 0·2 in. diameter showed a ratio of dynamic to static strength of 1·54 for 11·78 ft./sec. At 16·68 ft./sec. and 29 ft./sec. this material failed; so did the specimens of 1 in., $\frac{1}{4}$ in. and $\frac{1}{32}$ in. under dynamic loads of high speed with the exception of annealed aluminium of 1-in. length showing a ratio of dynamic to static strength of about 1·5 (Fig. 21).

The other materials, such as duralumin, brass ("as received" and "annealed"), magnesium alloys and zinc behave mostly in the same manner; that is they stood the dynamic tests up to a speed of 29 ft./sec. (except magnesium alloys) for specimens of cylindrical shape and 2-in. gauge length; even for 1-in. gauge length the resistance is fairly good for most materials, while for $\frac{1}{4}$-in. gauge length they all failed at a speed of 29 ft./sec. (cold-drawn brass had already failed at 16·68 ft./sec. and zinc and magnesium alloys at 11·78 ft./sec.). Furthermore, as in the preceding test series, none of the sharp notched specimens of these metals stood any dynamic loading (Fig. 21).

Discussion of Test Results

The results of this investigation showed that the materials, tested in the form of notched specimens, behave in a quite characteristic manner under static as well as under impact loads at various testing speeds. In this respect most materials can be classified into three groups.

The first group comprises most of the cast alloys which are less ductile than wrought materials and which present practically no resistance against impact loads of any importance. These cast materials are very brittle at low impact speed, whether the specimens are cylindrical or notched. Unlike other materials, the shape of the working volume under dynamic loads is, for most cast alloys, without any practical influence on their impact resistance which, very often, is completely negligible.

In the second group, materials such as wrought aluminium and aluminium alloys, copper and copper alloys, magnesium alloys, iron and iron alloys, behave differently. For cylindrical shaped specimens of these materials, with a gauge length of at least $\frac{1}{4}$ in., the resistance as well as the elongation increase with increasing deformation speed up to 29 ft./sec. The same may be said of specimens with shorter gauge lengths or with a V notch of large angle (160° and 90°) with the basic difference, however, that in this group the speed of deformation during plastic flow of the material is of prime importance insofar as there is a very pronounced sensitivity of the material in the root of the notch, with increasing speed. A sharp decrease of the dynamic strength, down to practically zero, can be easily observed with these materials presenting a reduced working volume under plastic flow due to a more or less sharp notch. The resistance of U-notched or V-notched materials may fall down to practically nothing at a fairly low loading speed, as has been observed, for instance, for brass, duralumin or magnesium alloys. The materials in this group do not show a sufficient resistance in the root of the notch, especially under the higher deformation speeds. The material, under such conditions, is substantially weakened, due to an insufficient capacity of local flow, the direct cause of an insufficient dynamic resistance.

The third group includes the extremely tough materials such as Monel metal and some special steels whose resistance, elongation and total energy absorbed up to the breaking point increase rapidly with increasing deformation speeds, when tested in the form of cylindrical specimens. With the introduction of various notches, whether in the form of a U or a sharp V, the resistance increases in proportion with the loading speed and the reduction of the volume of material under flow (notching effect). Moreover, the total energy necessary to break all shapes of specimens is greater or at least

about equal to that of the static test. These materials possess the valuable property of flowing locally at the bottom of the notch, even under high deformation speeds. That is the plastic flow of these materials is accompanied by an increase in strength and no brittle type fracture of the materials at the root of the notch, due to the prevention of plastic deformation, occurs. This means that in the neighbourhood of the fracture, as may be seen clearly on the tested specimen, the material is able to flow even if a sharp notch is provided and consequently it shows a greater total energy absorbed than materials with a pronounced brittle-type fracture.

As may also be observed, the critical speed at which the resistance of the material falls down rapidly is quite different from one material to another and is, for less ductile materials, substantially lower than for materials with a high local capacity of deformation. It can be stated that there exists, for each material, a critical speed at which it cannot flow fast enough to follow the deformation process and consequently does not show the characteristics of a metal with great deformability and flow, but those of a brittle material. For these materials, the fracture is due to a pure shearing process. Considering that the mechanical properties of structural materials are greatly dependent on the local tensions due to the shape of the loaded element as well as on their capacity of instantaneous local flow, it seems of prime importance to the designer to consider the resistance of these materials from the point of view of the shape in which they are to be used and the loading speed they will have to withstand. The test results show, further, that the mechanical type of apparatus used for recording the stress-strain diagrams of the specimens is not sensitive enough for specimens breaking with low absorption of energy, as is the case for most notched materials under high impact speeds. For these tests, the diameter of the notched specimen could be increased so as to reach a breaking energy which would be higher than the minimum range of the apparatus. By this means, the records would be representative of the energy absorbed by the specimens. For higher velocities, as for instance, when using speed ranges up to a few hundred ft./sec., the development of a new device, based on the principle of a practically massless piezoquartz, might be the right answer to the problem.

Conclusions

1. A new type of equipment has been developed for recording in a very short time the force-elongation curves of specimens under impact loads. A tangential dynamometer with spiral springs adjusted between thin steel strips records the dynamic load, while simultaneously the elongation of the specimen is recorded by the rotating movement of a drum in a direction perpendicular to that of the load applied. The new apparatus can be used with striking velocities up to 29 ft./sec. and a maximum dynamic load of about 3,000 lb. By a special device the ultimate load recorded by the drum can be checked within an error of less than 1%.

2. To obtain the higher striking velocities a new impact pendulum hammer of a maximum capacity of about 500 ft.-lb. was designed and constructed.

3. Tensile tests carried out under impact load on specimens of various gauge lengths ($\frac{1}{32}$–2 in.) and of 0·15 in. and 0·2 in. diameter, for six different materials, show that the total energy absorbed by the specimen decreases rapidly with decreasing gauge lengths. The energy absorbed per unit volume, however, increases rapidly with decreasing gauge lengths and reaches very high values for sharp-notched specimens.

4. Tensile tests carried out on identical specimens in two different impact machines (Olsen and Riehle) gave results in fairly close agreement for the energy absorbed.

5. Results of static tensile tests on specimens of various gauge lengths ($\frac{1}{32}$–2 in.) and 0·2 in. diameter, made with a rate of straining of about 0·0005 ft./sec., were compared with the results of dynamic tests on specimens of same gauge length at a speed of 11·78 ft./sec., a rate of straining which is about 20,000 times faster than for the static tests. The results of static tests show very clearly the notching effect characterised by a higher ultimate load and a smaller elongation for most materials. The ratio of dynamic to static strength was the lowest for brass at 1·43, and went up to 1·85 for mild steel. Furthermore, the total energy absorbed was, for all materials, higher in the dynamic than in the static test, both decreasing rapidly with decreasing gauge lengths. A comparison between the various materials of the energy per unit volume necessary to break the specimen, both in the static and the dynamic test, shows that it is highest for Monel metal, medium and mild steel. Compared with brass and aluminium these values are, for notched specimens, from 7 to 10 times higher (Fig. 10–15).

6. It seems that the strength per unit volume might prove a much more reliable standard than the strength calculated per unit area, for evaluating different structural materials. It is the volume of the structural member that absorbs the applied load (static or dynamic) and not the section.

7. Unpublished results of static and dynamic tests, previously carried out with speeds of 3·4 and 4·8 m./sec., show that for steel the dynamic strength increases with increasing loading speed and reaches a ratio of dynamic to static strength of about 1·47 with cylindrical specimens of about 2-in. gauge length. By introducing V and U notches in cylindrical specimens, not only the static strength but also the dynamic strength is increased; the results show that the static strength is increased about 1·63 times.

Duralumin and brass cylindrical specimens show also an increase of strength under dynamic load; with V and U notched specimens, the static strength increases, but the dynamic strength decreases. Unlike the wrought material a sharp notch in the cast iron specimen does not increase its breaking strength either static or dynamic. Under dynamic loads the resistance of this brittle material suffers a loss of more than 95% (Table III), as compared with the cylindrical specimen.

8. The influence of speed on the tensile characteristics of 2-in. gauge length cylindrical specimens loaded statically and up to 29 ft./sec. is characterised by a pronounced increase of their resistance with gradual increase of the loading speed. Thus, for instance, the ultimate load of brass, aluminium and magnesium alloys tested at a speed of 11·78 ft./sec. is from 33–55% higher than the ultimate load in the static test; tested at the same speed, zinc even stands a load 100% higher than in the static test. At higher loading speeds, the ultimate strength still increases (aluminium alloy and brass about 76–92%). For zinc, the increase amounts to 137% at a speed of 16·68 ft./sec., but drops to 119% at 29 ft./sec.

The increase in elongation is also very pronounced for all materials except zinc for which the elongation is smaller under dynamic loads.

9. Load-deformation diagrams of cylindrical and notched specimens tested under static and dynamic loads indicate that the static as well as the dynamic strength of soft metals, such as copper, aluminium and zinc, is increased by providing a V notch in the specimen; with the introduction of a sharp U notch, however, the dynamic strength is substantially smaller than for the cylindrical specimens. The same may be said for aluminium and zinc, the latter showing, with a V notch, a smaller dynamic resistance.

10. Static and dynamic tests were made on cylindrical and notched specimens of 24 metals and alloys of various heat-treatments at testing speeds of 0, 11·78, 16·68 and 29 ft./sec. The results illustrated in Figs. 19, 20 and 21 show that the notching effect under static loads is very pronounced for all materials except cast iron. Moreover, the dynamic strength increases with a decreasing gauge length, which means also a decreasing working volume of the specimen, down to a certain minimum value depending on the ductile properties of the materials tested and on the effective speed of the impact load. Most notched materials are extremely sensitive to impact loads of high speed; structural materials such as duralumin, magnesium alloys and brass, with a flat V notch, do not resist any dynamic load; even very ductile materials such as copper, zinc and aluminium stand this test to some extent only in the annealed condition, while cold worked they behave, with a notch, like brittle material. Grey cast iron is the weakest of all materials tested and does not stand any substantial dynamic load. On the contrary, Monel metal, a really tough and ductile alloy, stands all the dynamic tests in a perfect manner, whether notched or not; no rupture takes place and it behaves, in this respect, much better than mild and soft steel tested under similar conditions.

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The Cleaning of Metals

Part I—Choice of Process and Cleaning Agent

By R. Groves

The cleaning of metals is becoming increasingly important, if only because so many operations now depend for their success on the complete elimination of dirt, oil, grease, etc., from the surfaces of the parts to be handled or treated. In the following article and its successors a full account will, therefore, be given of the primary points to be considered in choosing and using the processes, materials and appliances for metal cleaning.

THE actual cleaning material adopted is governed by the character of the substance to be eliminated from the surfaces concerned, and the types of metals on which they occur. The process to be used is decided by the form of the castings or other pieces, and the appliances or apparatus are dependent on the output desired and the process. There are thus three main factors, material, method and machine, and each of these can be sub-divided into further qualifying considerations. Thus, the choice of cleaning material will be affected by the state of the pieces to be dealt with; by the kind and degree of tenacity of the foreign matter to be removed; by the extent to which cleaning must be complete; and by the metal concerned.

Choice of cleaning process will be affected by the form of the pieces, their dimensions and their mechanical strength. Choice of cleaning appliance will be governed by the rate of output per working hour; the type of finish, e.g., wet, dry, hot or cold; the extent to which additional operations are to be included; the available equipment for bringing cleaning solutions to the correct temperatures; the room available; and the location of the operation in the production sequence.

Other factors that will also have to be borne in mind are the comparative total costs of the different cleaning agents, processes and apparatus.

Choice of Process and Cleaning Agent

The first point to be considered is whether or not the operation is to be carried out by hand or mechanically. It is not always economical to instal a machine, because the actual number of parts to be cleaned may not justify mechanical appliances, while the rate of output may not justify a *fully* automatic machine even when the number of parts is fairly large. We will, therefore, consider the factors under the above heading individually, in order that their bearing on the problem may be ascertained.

In many instances, the parts to be cleaned are not heavily coated with foreign matter, and can be cleaned by processes and agents that would be ineffectual if the deposit were thicker and more adherent. Whatever the type of dirt and whatever the degree of adhesion, this still obtains. The dirt may be more difficult to remove if there has been high temperature or pressure during the processing of the metal. Some types of dirt have a bad effect on the cleaning solutions and this is a particularly important point when the coating is thick, because it materially affects the service life of the cleaning material.

The generic term "dirt" includes whatever is considered undesirable on the surface of a metal, so that a term as wide as this is hardly helpful when the specific

problem of cleaning is under consideration. It is vital that the precise character of the material to be removed should be understood. Some foreign matters are easily removed by one type of cleaning agent, and totally unaffected by others. The "dirt" to be cleaned off may be a cutting compound, a lubricant, a coolant, a drawing or stamping lubricant, a polishing or buffing compound. All of these differ considerably in composition, and it is, therefore, insufficient to indicate merely that a "cutting compound" or "lubricating material" must be removed. The specific composition of the substance must be known before the correct cleaning agent can be chosen. This information must be obtained, where it is not already known, either from the maker or as a result of tests made in the laboratory.

Types of Dirt

There are, as indicated, various types of dirt. In Fig. 1, for example, is shown a number of solid particles of dirt firmly united and maintained in union by films of grease or oil. In Fig. 2, enlarged considerably, appears an oil film on a metallic surface. Fig. 3 shows a solid particle of dirt maintained in place on a metallic

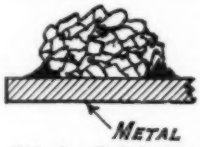

Fig. 1.—Solid dirt.

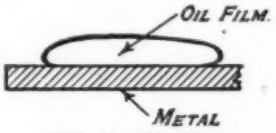

Fig. 2.—Oil film.

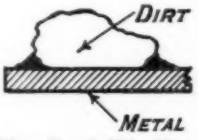

Fig. 3.—Solid dirt held by oil or grease.

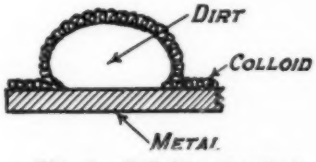

Fig. 4.—Colloids absorbed by dirt.

surface by a film or smear of grease or oil. Fig. 4 shows colloidal particles absorbed on the surface of a solid particle of dirt, and adherent to a metallic surface.

It is not uncommon in workshops to find that although a particular cleaning process has been successful for a long period, it fails all at once to produce the desired result, although no change in method or material used has been made. It is usually discovered on inquiry, that the reason is a variation in the lubricant or compound or other form of "dirt" existing on the metals treated, and in consequence the presence of constituents not responsive to the process employed.

A point worthy of mention is the advisability from the economic point of view of purchasing coolants, compounds, etc., of the types enumerated and especially those used in drawing and stamping, such as can easily and efficiently be dealt with by the more usual cleaning agents, as this obviates the necessity of using special cleaning agents and processes for the sake of a particular lubricant. The only exceptions to this rule should be those in which the advantages to be gained by the use of a special compound outweigh the disadvantages of having to use special cleaning methods.

Removing Swarf and Chips

One of the hardest problems in metal cleaning is the removal of swarf, chips, dust, oxide and miscellaneous solid dirt in particle form, yet materials of this type are found on almost every metallic part dealt with in engineering and other workshops. Moreover, numerous parts are sent for cleaning after they have already been in use, so as to render them suitable for regulation, modification, repair, as by welding, or rectification. These may carry on their surfaces materials ranging from clotted oil and grease to abrasive substances, sand, mud, tar, and carbonised oils or greases.

The degrees of adhesion of the dirt is, as stated, an important factor. There may be only a light dust, such as a metal casting might get from lying on the sandy floor of a moulding shop or from being stored in a grinding shop, where dust from the air settles on it. Such dirt could almost be blown off. On the other hand, millscale and carburised patches on steel present exceptional difficulty, being composed of iron oxide and a finely divided form of carbon. The light dust could easily be washed off by merely immersing the part in a tank of suitable solution. The other would need highly specialised cleaning processes and materials. There are, of course, many degrees of adhesion in between these extreme cases.

It is the degree of adhesion that largely decides whether the cleaning material is to be of alkaline, acid, solvent or emulsifying type.

We may now turn to the degree of cleanness required, which also helps to decide the material and process used. For parts that have to be painted or lacquered, it is usually considered essential to give the metal a surface entirely free from coarse superficial dirt. For parts to be electroplated, it is essential that all films of grease and oil are so thoroughly eliminated that when the metal surface is "wetted" by the solution, there is no point or area where, owing to the presence of oil, the water film is discontinuous. All solid dirt must likewise be removed, because if left on, it might interfere with the success of the plating operation. For the same reason oxides, scale, stains, etc., must be carefully cleaned off.

Types of Cleaning Agents

Some operations do not demand so high a standard of cleanliness. It is not necessary for assembling, rough painting, or inspection, to be so thorough in dirt removal as for the processes mentioned above. Hence, the precise cleaning material used is partly governed by the purpose for which the part is required, and the material in turn decides the design and construction of the machine used.

The principal types of cleaning materials are: (*a*) alkalis; (*b*) degreasing solvents; (*c*) petroleum products; (*d*) emulsifiers; (*e*) acids. In general, it is advantageous to confine a particular type of cleaning machine to a particular type of cleaning material, because in this way superior results in rate of production, quality and economy are obtained. There are, however, some cleaning machines that need little modification to adapt them to a different type of cleaning material.

The influence of the cleaning material on the type of metal is the next important factor. Many types of dirt, many degrees of dirtiness, and many degrees of required cleanliness, suggest in themselves an alkali as the most suitable cleaning material, but in practice there are certain metals that cannot be cleaned with an alkali, e.g., brass, zinc or aluminium, for the reason that they react with an alkaline cleaning agent and

may in certain circumstances cause it to produce severe staining of the metal or even a degree of corrosion. Such metals need an emulsifier which does not corrode or tarnish them. Consequently, unless the form of the pieces to be dealt with is such as to render the use of an emulsifying cleaner impracticable, there are many advantages in using one, and then the type of metal becomes unimportant.

Cleaning Processes

Probably the majority of metal cleaning is still carried out with alkalis, but this process has its limitations. Chlorinated solvents for vapour and liquid phase degreasing are sometimes used when no other process serves. Petroleum solvents are widely employed in this method for dipping and spraying where water solutions cannot be used because of the risk of rusting where parts cannot be effectively dried. The method is, however, not satisfactory and has an element of risk.

Emulsifying agents have many advantages. Acids are much employed as a means of preparing metallic surfaces for painting while at the same time removing grease, scale and rust. They also prove effective for giving steel a temporary resistance to rust in advance of other finishes.

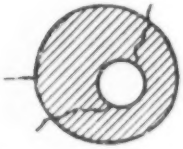

Fig. 5.—Surface tension breaks film of soap.

Fig. 6.—Needle floats on water by not breaking tension.

Taking these various processes in turn, the alkali cleaner has the advantage that it emulsifies the majority of greases and oil, while it is also relatively inexpensive and can be applied by means of a high pressure spray This means that the chemical action of the solution is enhanced by the purely mechanical action of the high pressure. In the early days, the alkalis used were caustics, but these were not highly efficient and were difficult to wash off with the necessary speed and thoroughness. In consequence of these drawbacks and because the caustic alkalis did not wet the metal as effectively as is necessary, thus losing cleaning time through inadequate penetration and cleaning, it soon became necessary to use a modified type of alkaline cleaner, even for those operations in which maximum alkalinity was essential. The desired degree of alkalinity is now obtained by using alkaline salts instead of alkalis based on caustic. These are less unpleasant and dangerous; but it should be noted that high alkalinity cleaners are still liable to cause skin injury and burns, so that every attention must be paid to the safety of the operator. The danger is, however, less than with the old type of alkali cleaning medium.

Making up Alkaline Solutions

The choice of alkaline salts for cleaning in the modern workshop involves not only ensuring the correct degree of alkalinity, but also the ability of the salts to yield, by hydrolysis, extra alkalinity progressively in proportion as the reaction of the solution on the dirt to be removed lower the original alkalinity. This is known as "buffer action" and it serves to keep the alkalinity of the solution constant throughout its working life.

The solution must also thoroughly wet the metallic surface being cleaned, as this enhances the rate of penetration of the cleaner into the accumulations of foreign matter. To ensure this, it is desirable to introduce a wetting agent into the solution and, in addition to the beneficial effects mentioned, this also makes it much easier to rinse off the solution after the parts have been cleaned.

Fig. 5 shows an aspect of surface tension. Here a loop of thread is shown laid on a film of soap formed in a wire ring. Surface tension fractures the film inside the loop and draws the loop into a true circle. In Fig. 6, a needle is shown resting on water. It will be seen that it perceptibly depresses the surface film but does not break it, and is therefore able to float. Fig. 7 shows how a wider concentration range is afforded by a solution having a buffer action.

Lastly, the ability of the cleaner to be easily rinsed off is important, because the metallic surface must be protected against any risk of corrosion or staining by the solution irrespective of the use to which it is later to be put.

In the next section further notes on alkaline cleaning solutions will be given.

Awards

Sir Edward Appleton, F.R.S., and Sir Robert Robinson have been awarded the £8,000 Nobel Prizes for science, the former for physics and the latter for chemistry.

The degree of D.Sc. has been conferred upon W. T. Pell-Walpole at the last degree congregation of the University of Birmingham. He has also been awarded an I.C.I. Research Fellowship in Metallurgy and in continuing his work on the melting and casting of tin bronzes.

Nickel Cast Iron Data Book

The Mond Nickel Company Limited have issued this month, a publication which will be of considerable value as a book of reference for the use of the foundry trades and, indeed, to every engineer concerned with cast iron. The "Nickel Cast Iron Data Book" is a revised and amplified edition of a similar book, first produced in 1939. This was in great demand during the war, even in its abbreviated form, and it is felt the new publication, as a loose-leaf pocket edition, will be equally sought after. As will be known to holders of the earlier edition, it contains a mass of information on technique, cupola practice, weights of charges and, in fact, every aspect of the founding of the many types of nickel alloy cast iron now in use for engineering construction.

International Nickel Interim Statement

The Interim Statement for the nine months ending September 30th, 1947, issued by The International Nickel Company of Canada, Ltd., shows a net profit in terms of U.S. currency of $23,522,911 after all charges, equivalent after preferred dividend requirements to $1·51 a share on the common stock.

This compares with net profit of $19,556,009, equal to $1·24 a common share, in the corresponding period a year ago.

Board of Trade Committee's Final Report on Patents

By S. T. Madeley

Much careful thought has been given to British Patents by what has become known as the Swan Committee. First and second interim reports of this Committee have been issued, and the final report has recently become available, a summary of which is given in this article.

AFTER over three years of work the Departmental Committee of the Board of Trade appointed in April, 1944, has come to an end of its labours. In September, 1947, the Board of Trade Committee, more generally known as the "Swan Committee" after its chairman, Mr. Kenneth R. Swan, K.C., issued its Final Report; it had already issued a First and Second Interim Report.

The First Interim Report dealt with extensions of term of patent for war damage or loss and recommended that the Comptroller should be empowered to grant such extensions. These recommendations were given effect to in the Amending Act of 1946. The Second Report dealt mainly with patent litigation, subject-matter, abuse of monopoly and chemical and food and medicine patents. Amongst the recommendations made were that the Comptroller should have the power to try patent actions for infringement subject to certain conditions and that to some extent he should be empowered to consider subject-matter (inventiveness) and prior user in patent procedure.

The Third Report deals with the first twenty sections of the Patent Acts. It is mainly directed towards recommendations dealing with the applicant, employer and employee, the date of the patent, third-party rights, Crown-user of inventions, chemical products, joint ownership of patents, "convention" applications, exclusive licenses and infringement actions, declaratory judgments and exploitation and development of patents in the public interest. A summary will now be given of the recommendations of the Committee.

Lodgment and prosecution to grant of patent application should be permitted to an assignee of an invention.

Benefit of an invention or of a patent when an employer and an employee are jointly entitled thereto, should, in the absence of written contract, be apportionable by the Court.

Where employers and employees agree to submit disputes to the Comptroller, he should be empowered to decide them.

As regards disclosure of the invention concerned, the effective priority date of a patent should be the date of filing the basic document—i.e., provisional, complete or foreign (in convention cases) specification as the case may be. As regards other matters, including terms and payment of renewal fees, the date of a patent should be the date of filing the complete specification. The novelty search should be brought up to the date of filing the complete specification, but an applicant should be able to rely on his effective priority date above mentioned, where necessary to meet anticipatory documents.

When intervening publication is absent, disconformity between the complete Specification and the basic document, provisional or foreign Specification, should not form a ground for refusal of grant.

The standard conditions for the protection of third-party rights in cases of regrant should be that any person who is not a licensee under the relevant patent at the date of its expiry and who after the date of the expiry and before the date of its advertisement in the official Journal (patents) or the application for regrant has made use of the patented invention shall be considered as having done so with the licence of the patentee and shall be entitled to continue to use the said invention, without infringement, as far as allowed in the schedule to the order of re-grant.

The Court should retain complete discretion as to conditions of re-grant, and the standard or special conditions should be inserted in all orders for re-grant, subject to the right of interested parties to be heard for the purpose of informing the Court of special circumstances calling for special conditions. The conditions should deal specifically with the form of subject-matter claimed.

Third parties who make use of the patented invention and who know or might know that an application for re-grant is to be made should usually have no merit.

The schedule should deal with an article, apparatus, or process for the production or treatment thereof separately.

War emergency litigation should be permanently incorporated in the section of the Acts relating to Crown-user.

Where Crown-user causes a person to lose benefit under his agreement regarding use of a patented invention he should be entitled to make application for a proportionate share of Crown compensation paid for the said Crown-user. Pending cases should be covered by the Crown-user section and so should cases where the patentee or his licensee is employed as Government contractor to manufacture the patented article. Issues of validity and infringement should be open to decision by the Courts without the consent of the parties being necessary.

Provided that it be not possible to claim a substance when found in nature, claims for substances prepared or produced by chemical processes or intended for food or medicine should not be limited to the methods or processes described in the specification or their obvious chemical equivalents.

Assignment of any of his interest in a patent by a co-owner should only be effectable with the consent of his co-owners. A co-owner or his agents or contractors should be able to use the patented invention without the express licence of his co-owner being first obtained.

In Convention Applications it should be permissible to combine in one British application subject-matter

contained in basic applications in more than one convention country. It should also be allowable in convention cases to combine subject matter which was not contained in the basic specification provided such additional subject matter only takes the British filing date.

Convention documents should not be laid open to public inspection until a case is in order for allowance.

An exclusive licensee should be able in his own name to take action for infringement and obtain normal relief therefor.

A potential manufacturer of an article should be able to obtain a declaratory judgment as to whether the said article would infringe a particular patentee when the relevant patentee will not give a satisfactory answer.

Inventions owned or subsidised by the State should be treated as an asset of the public. They should be vested in a central body which can estimate their potential value and arrange for their industrial development.

Three months extension of time should be allowed for filing a complete Specification after a provisional.

Unauthorised prior publication of his invention should not be prejudicial to an applicant.

When a Comptroller is made aware of an anticipatory document otherwise than as a result of the official search or in opposition proceedings he should be able to require amendment of the Specification or to refuse the patent. He should also be able to insert in a Specification a specific reference to an earlier patent in force and *prima facie* valid which the invention sought to be protected would, in his opinion, infringe.

In cases of prior grant, greater latitude for amendment should not be required until the earlier patent is actually granted. Twelve months, extendible to fifteen, should be allowed from the date of lodging a complete Specification for putting a case in order for acceptance.

Unaccepted complete Specifications of void applications if the applicant so requests or consents, should be printed and published; and printed copies of accepted specifications should have printed on them the date of printing and publication and their date should be the material date relative to the Acts.

It should be permissible to lodge an opposition to grant of patent within three months of publication of the accepted specification.

Grant should not be refused on the ground of prior publication when this results from breach of confidence.

No more than loss of priority date should occur on the sole ground that the convention priority date has been wrongly claimed.

Re-grant to the successor of a deceased applicant or of a defunct company should be possible when a patent has been granted to such in ignorance that they no longer existed.

The (Patent) Act should contain a specific statement of rights conferred by a patent grant.

Renewal fees should be payable into the Patent Office by others than the patentee.

Exclusive licensees should be allowed to apply for extensions of patent term.

Provided the complete Specification of a patent of addition is filed not earlier than the filing date of the complete specification of the main patent, the patent of addition should be allowed to bear an earlier filing date than the said main patent; and a patent of addition should be grantable for unanticipated subject-matter which is not inventive in view of the main patent.

An application for restoration should be permissible without joinder of co-patentees.

Where sealing fees have not been paid through inadvertence a lapsed patent should be restorable.

An account of profits instead of damages should be claimable by a successful plaintiff.

Notification of existence of a patent should not constitute a threat of an infringement action.

Swedish Grant for Atomic Research

The Swedish Government recently granted a little over half a million kroner (£35,000, $139,000) for atomic energy research in Sweden. The sum was distributed to several scientists and institutions working on nuclear physics and chemistry. The biggest grant, 200,000 kroner, was made to the famous Professor The Svedberg for the cyclotron, which is being built at present at his Upsala laboratory.

Awards to Swedish Steelworkers

In connection with the recent 85th anniversary of the Sandvik Steel Works—one of the biggest in Sweden—930 of its employees were awarded the Company's medal for merit, instituted ten years ago. About 120 of them have been in the Company's service for more than 40 years, and some of the oldest veterans can look back upon 55 years' continuous service and even had sons among the medallists. A 70-year-old worker, Emil Källberg, had never had another job and never been sick for a single day in 55 years. The medals were distributed by the Head of the Sandvik Works, Mr. K. F. Göransson, at a banquet in the big indoor hall at "Jernvallen," the Company's big sports ground for all kinds of indoor and outdoor sport.

Tube Investments start Pensions Scheme

Tube Investments are offering to the 25,000 men and women operatives employed in the works of subsidiary and associated companies a scheme of pensions and life assurance, to start from December 1st, 1947. A similar scheme already exists for staff. It provides a life pension for men from 65 and for women from 60, varying in amount according to their wage rates and years of service; and a substantial life assurance during the years of employment.

As a contribution to the scheme, Tube Investments will subscribe over half of the weekly payments for each pension, workers' payments being kept low because of the full contribution shortly required of employees under the State Pension scheme. A further payment, estimated at between £600,000 to £750,000 is being made to secure benefits for past service by employees without their subscribing for the years before the scheme started; and they will also bear the whole cost of the life assurance.

The Board of Tube Investments believe that long service in productive employment calls for special recognition. They are glad the Company is in a position to implement this principle in such a manner that every worker who joins the scheme and who retires from December, 1948, onwards will be entitled to a pension as a supplement to the State pension. They hold the view that the present economic position of the country is no reason for delay in putting a scheme like this into effect.

MICROANALYSIS
CHEMICAL AND PHYSICAL METHODS
APPARATUS METALLURGICAL APPLICATIONS TECHNIQUE

"ACADEMIC training in analytical chemistry must be made to conform with the present needs of industry." This is the theme underlying an interesting article in a recent number of "Analytical Chemistry," and inspiring the editorial in the same issue. From both of these, the conclusion is obvious that instrumental methods in teaching courses have not yet caught up with the requirements of industry. Recommendations to meet this shortcoming are proposed, and merit thoughtful consideration. It is of interest to note that it is specifically stated that "inclusion of microchemistry as an undergraduate (and graduate) course seems necessary if a balanced programme in chemical analysis is to be presented." Another point stressed, one frequently overlooked, is that while the obvious connection between analytical and inorganic chemistry is usually realised (often to the extent of fusing the teaching of these under one set of instructors) it is not so widely appreciated that the analytical chemist must learn to tie up his physical chemistry and his organic chemistry equally closely with his own branch. There are statements in these articles with which we find ourselves less in agreement. We feel that it is dangerous to claim that "good analytical technique is acquired when needed on the job," and that hence accuracy is not of fundamental importance in training. All analysis, as all chemistry, is an exact science, and the child in this, as elsewhere, is father of the man. To allow that accuracy is of secondary importance is to admit the thin edge of a very large wedge, and we feel that it may be ill-advised, to say the least. But the articles deserve close study and can provide us with much nourishing food for thought.

Some Applications of Inorganic Chromatography

By G. Robinson

Chief Chemist, W. Fearnehough, Ltd., Sheffield

A description is given of some qualitative and quantitative applications of chromatography, with suggestions for further methods of application to the microanalysis of alloys. The principal application described is the use of 8-hydroxyquinoline as an adsorbent for Cu, Ni and Zn.

THE initial work in this field was due mainly to Schwab and Jockers,[1] who experimented with the separation of metallic cations on an alumina column. The method is similar to that employed in organic work, though the method of banding appears to be somewhat different. Organic separations depend on actual adsorption at the surface of the particles of the packing medium, hence, more strongly adsorbed components form bands at the top of the column with less strongly adsorbed ones beneath. Thus, further additions of solvent cause gradual migration of the bands downwards. Also, bands may be separated by zones of adsorbate-free alumina. With inorganic materials however, further washing causes little or no movement of the bands and there is usually no separation between them. Apparently the banding depends on the formation of actual precipitates rather than adsorbed films, though initial adsorption may be necessary to further the reaction, probably in a manner analogous to the enhanced reactivity of surface adsorbed gas films.

This difference between organic and inorganic chromatography would appear to be beneficial rather than otherwise, since as the latter depends on a truly stoichiometric reaction there is likely to be correlation between length of band and percentage composition. A noteworthy feature of inorganic adsorption is that the metallic cations separate out in a definite order on alumina[2] (see Table I). This order may be varied by altering the conditions as will be shown later, and a

1 Zechmeister and Cholnoky, "Principles and Practice of Chromatography." Trans. by Bacharach and Robinson, 2nd ed., Chapman and Hall, 1943. Beaucourt and Masters, *Metallurgia*, 1945, **32**, 181.

2 Schwab and co-workers, *Naturwiss*, 1937, **25**, 44; *Angew. Chem.*, 1937, **50**, 546, 691; 1938, **51**, 709.

further definite though different series is found when using the ammine or tartrate complexes (see Tables II and III).

The problem of identifying the adsorbed cations is somewhat complicated by their being colourless in many cases, but this difficulty may be overcome by the process known as " developing," in which, after suitable washing (usually with water), a reagent producing a coloured salt or complex with the desired ion, is passed through the column. Two useful developers in this respect are ammonium sulphide and potassium ferrocyanide. An interesting point arises here, showing the ease with which the position of a zone may be altered by choice of a suitable developer, and turned to account in determining the presence of a particular component. If a neutral solution of a copper-nickel alloy be adsorbed on an alumina column, considering the primary adsorption series (Table I), the copper will be found to separate

As
Sb
Bi
Cr Fe $^{+++}$ Hg
UO_2
Pb
Cu
Ag
Zn
Fe $^{++}$ Ni Cd Co
Tl
Mn

TABLE I.—Primary adsorption series of metallic cations on alumina.

above the nickel and may easily be seen from its distinctive pale blue colour. The nickel is usually of so pale a green as to be hardly visible. If now the chromatogram be developed with an ammoniacal solution of dimethylglyoxime, the copper ammine formed is washed right through the nickel band, and ultmately right out of the column. The nickel band remains fixed as the easily visible red nickel dimethyglyoxime complex. This method affords a simple means of separating and determining the two metals, the copper by ordinary volumetric technique, and the nickel either by measuring the length of band compared with that from a solution of known strength chromatographed under precisely

Co
Zn
Cd
Ni
Ag

TABLE II.—Order of adsorption of ammine complexes on alumina.

similar conditions, or by complete solution of the portion of the column containing the metal and finishing by any of the familiar methods for nickel.

This method has been attempted in the determination of small amounts of nickel in steel, by washing out the iron as the alkaline tartrate complex. Unfortunately the ferric ammonium tartrate appeared to promote mobility of the nickel band and some nickel passed into the filtrate with the iron. Somewhat better results have been achieved by pre-coating the alumina with dimethylglyoxime and developing with alkaline ammonium tartrate. Further experiments show that alumina coated with salicylaldoxime is likely to give better results in this case than the dimethylgloxime. In many cases it has been found that coating the alumina before use, with a suitable specific reagent for the metal

Ni Co Zn Cd Mn
Pb
Cu
Bi
Fe
Cr

TABLE III.—Order of adsorption of tartrate complexes on alumina.

required, seems to give better results than by washing the already adsorbed metal ion with a solution of the reagent as developer. This has been found particularly to apply to the use of sodium di-ethyl-di-thio-carbamate for detecting and determining copper.

Application to Brazing Alloy

So far, little use has been made of the foregoing type of reaction for either qualitative or quantitative analysis. It seems probable, however, that a modified form of procedure using what might be termed an " organic adsorbent " may be developed as a means of determining inorganic, notably metallurgical products. In 1939 Erlenmeyer and Dahn[3] showed that if a solution of certain metallic salts was passed through a column of 8-hydroxyquinoline, selective banded separation of the metallic ions takes place (see Table IV) and it is an application of this method that forms the principal part of this paper.

The problem to be tackled was the determination of the variation of zinc content in a brazing alloy during brazing, and whether the loss of zinc could be expected to be constant with a given initial alloy and constant heat-treatment procedure.

VO_3^-	Dark grey.
WO_4^{--}	Yellow.
Cu^{++}	Green.
Bi^{+++}	Yellow.
Ni^{++}	Yellow.
Co^{++}	Reddish.
Zn^{++}	Yellow.
Fe^{+++}	Black.
UO_2^{++}	Orange.

TABLE IV.—Order of adsorption of metallic cations on 8-hydroxyquinoline.

Since the final sample could only be obtained from scrapings from the thin line of " brass " on the finished product, the amount of sample was accordingly limited to a few milligrams, hence, the need for a new technique.

The initial experimental procedure aimed at discovering the optimum conditions governing the use of 8-hydroxyquinoline as a chromatographic adsorbent, and the degree of reproducibility to be expected from the method. Accordingly four test solutions were made up, each containing the equivalent of 2 milligrams of metal per millilitre as follows :—

A Zinc Acetate (2 mgms Zn per ml)
B Copper ,, (2 ,, Cu ,, ,,)
C Nickel ,, (2 ,, Ni ,, ,,)
D Brazing alloy (2 ,, metal per ml) solution

The solution D was made by dissolving 2 gms. of the brazing alloy (Cu 62·25% ; Ni 16·3% ; Zn 21·35%) in nitric acid (s.g. 1·20) making alkaline with ammonia and just re-dissolving the resultant hydroxide with acetic

3 Erlenmeyer and Dahn, *Helv. Chim. Acta*, 1939, **22**, 1369 ; 1941, **24**, 878.

acid. This solution was then diluted to 1 litre with distilled water.

Amounts up to 10 mls of these solutions were passed through experimental columns of 8-hydroxyquinoline when it was found that banding as in Table IV took place readily. As had been noted earlier by Erlenmeyer and Dahn it was necessary to mix some inert material with the oxine reagent in order to prevent distortion of the bands by mechanical movement of the reagent due to its slight solubility in water. Various diluents have been suggested, including starch, kieselguhr, barium sulphate and silica gel. Of these materials, starch was found to give the best type of banding though rendering filtration somewhat slow.

Another factor tending to produce channelling and irregular bands was found to be the acidity of the solutions, control of this factor was eventually effected by buffering the solutions at pH 5–6, with sodium acetate.

Reproducibility of band length was eventually obtained on solutions A, B and C with the following conditions :—

Adsorbent.—50% by weight each, of 8-hydroxyquinoline and " soluble " starch dried, and ground to pass a 60-mesh sieve and be retained on one of 80 meshes to the inch.

Tube dimensions.— 5 mms. internal diameter and a column length of 15–20 cms.

Solutions.—2 mgms. per ml. metal content was quite useful, but dilutions of from 0·5–0·05 that strength were satisfactory provided the pH range never departed from 5–6.

So far, experiments with single metal solutions were found under the above conditions to give accurately reproducible zone width, but the nickel and zinc complexes instead of being green and yellow respectively, as stated in the original literature were found to be of almost the same shade of yellow. Happily this obstacle to identification was easily surmounted when it was found that of the three complexes, Ni, Cu and Zn, only the zinc compound was fluorescent in ultra-violet light.* This fluorescence was of a distinctive bright green colour which made identification very rapid and simple when the mixed solutions and finally the alloy solutions were chromatographed.

From these preliminary experiments the proccdure was finally evolved for tackling the specific problem of loss of zinc during brazing, in the following manner :— A " referee " solution of the alloy in the " as received " condition was made up, by dissolving 2 gms. of the metal in nitric acid, fuming with 10 mls. of strong sulphuric acid, to replace the nitric, (sulphate soutions produced less solvent action on the columns, so giving sharper bands) and diluting to 1 litre with sufficient sodium acetate to give a pH of 5–6. The few milligrams (from 4–10) of the metal obtained after brazing were likewise dissolved and buffered at pH 5–6 at a dilution of about 10 mls. Then two identical chromatogram tubes were packed with the adsorbent. A volume of the referee solution containing the same weight of metal as the test solution was diluted to the same volume as the test solution and one solution passed through each tube and washed with an equal volume of distilled water in four or five portions. The length of the zinc zone was measured in each case in ultra-violet light and the variation of zinc content calculated by simple proportion as a percentage of the initial zinc content. These figures were then calculated to actual zinc content with the following results :—

			%	
Initial Zinc Content			21·50	
Final	,,	,,	15·00	All made under same conditions and time in furnace.
,,	,,	,,	15·00	
,,	,,	,,	15·00	
,,	,,	,,	17·50	Shortest time in furnace.
,,	,,	,,	10·50	Abnormal length of time in furnace.
,,	,,	,,	10·75	
,,	,,	,,	11·00	
,,	,,	,,	11·50	

The foregoing results would seem to suggest that in this or some similar method lies the future of the applications of chromatography in metallurgical analysis. One very valuable attribute of such methods would seem to be in the flexibility of the process and the fine limits of detection of trace materials which is available ; with the oxine method just described the original investigators claim to have detected 2 μg. of iron, and the author has successfully detected 5 μg. of zinc in the presence of ten times as much nickel and 2 mgms. copper, by using a tube only 2 mms. internal diameter.

In many cases the previously mentioned method of coating alumina with some suitable reagent would appear to offer promising results.

Unfortunately, 8-hydroxyquinoline does not lend itself to this technique for, as soon as water enters the column the aluminiumhy droxyquinolate complex is formed, so filling the tube with a continuous pale yellow band of almost the same shade as the zinc complex previously discussed. What is even worse, the zinc and aluminium hydroxyquinolates fluoresce with almost the same shade of green.

(*To be continued*)

* A special lamp was devised for production of the ultra-violet light, and this will be described in a subsequent communication.

Polarographic Discussion Panel

A MEETING of the Polarographic Discussion Panel of the Physical Methods Group of the Society of Public Analysts and other Analytical Chemists was held in the Concert Hall, L.C.C. Norwood Technical Institute, London, S.E.27, on Friday afternoon, 3rd October, when 40 members and visitors were present.

Members and visitors having been welcomed by Mr. W. A. Jackson, M.I.Mech.E., M.I.E.E., Chairman of the Board of Advisory Governors of the Institute, the chair was taken by Dr. W. Cule Davies.

Since the onset of an electrical fault had prevented a satisfactory demonstration when the Cathode Ray Polarograph developed by the staff of the Chemical Inspection Department, Ministry of Supply, was exhibited at a meeting of the Physical Methods Group during November last, the Committee of the Panel was grateful for its members to have the opportunity of observing the capabilities of the instrument under more favourable conditions.

The history of the development of the apparatus exhibited at the meeting having been described by Mr. A. S. Nickelson, the discussion on " The application of the Cathode Ray Oscillograph to Polarography " was opened by Mr. L. Airey. Having surveyed the fundamental phenomena upon which the formation of a polarographic wave depends, the speaker described the principle and construction of the apparatus on view. A potential " sweep," synchronised with the drop rate of the dropping mercury electrode, is suddenly applied

to the latter at a definite stage in the growth of the drop, when the substance being examined gives a diffusion current which rises rapidly to a peak and then decreases with the widening of the diffusion layer. The current, which is measured by the voltage drop produced across a resistance, causes a vertical deflection of the spot of a cathode ray tube having long afterglow characteristics, while the horizontal deflection of the spot is controlled by the potential applied to the dropping mercury electrode. The falling of the mercury drop terminates the "sweep," which, after a controlled time-lapse to permit growth of the new drop, repeats itself automatically. In this manner the trace on the screen of the cathode ray tube is repeatedly and reproducibly renewed.

For the comparison of solutions, the peak height is adjusted to a convenient fixed value, the ratio of the concentrations being determined from the dial readings of a precision resistor. The use of amalgamated silver or platinum micro-electrodes will certainly permit a simplification of the apparatus, which is more sensitive than polarographs commercially available.

Mr. Airey's remarks were illustrated by demonstrations by Dr. F. J. Bryant of the performance of the Cathode Ray Polarograph, including the isolation of the various waves occurring in the complex polarogram of a zinc-base alloy.

The discussion then ranged over various aspects, such as the probable cost of the instrument, training of personnel in its use, separation of waves, comparison with other types of oscillographic apparatus, etc. Among those taking part were Drs. Cule Davies and Morris, and Messrs. Haslam, Smith, Stock and Welford.

A Steam Oven for use in Microchemical Analysis

By Paul F. Holt
Department of Chemistry, Battersea Polytechnic

THE following describes an apparatus (Fig. 1) which is extensively used in this laboratory for heating and drying micro precipitates and for the evaporation of small volumes of liquid.

The apparatus consists of an inner tube of 30 mm. dia. which is drawn out to a nipple, *c*, at the lower end.

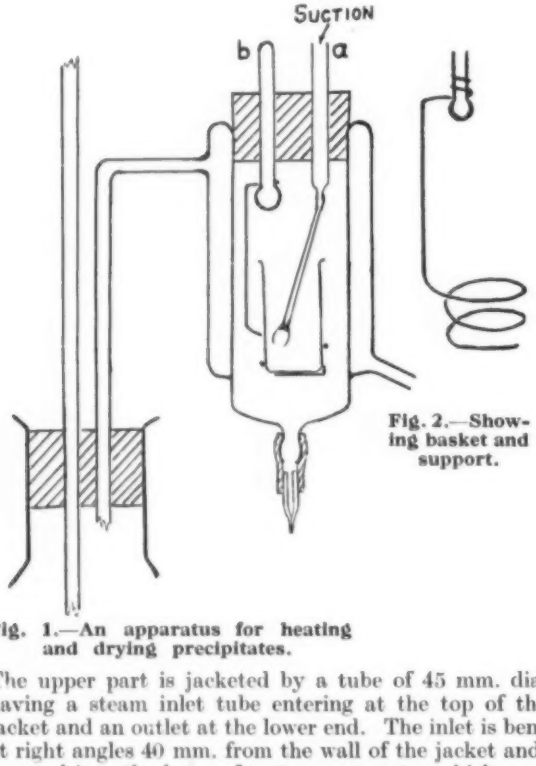

Fig. 1.—An apparatus for heating and drying precipitates.

The upper part is jacketed by a tube of 45 mm. dia. having a steam inlet tube entering at the top of the jacket and an outlet at the lower end. The inlet is bent at right angles 40 mm. from the wall of the jacket and, inserted into the bung of a steam generator which may conveniently be a 1 litre conical flask, serves to support the apparatus. The mouth of the heater is closed by a two-hole rubber bung, one hole of which carries a glass tube, *a*, drawn out at the lower end to approximately the diameter of the stem of a filter stick. The other hole carries a glass rod, *b*, with a knob at the lower end, the purpose of which is to support a basket of copper wire of the form shown in Fig. 2. The basket is thus removed with the bung of the apparatus.

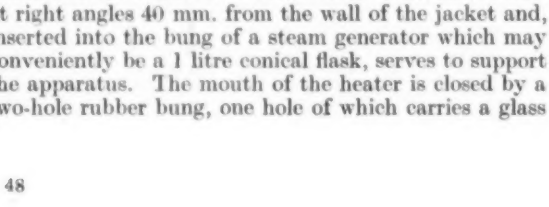

Fig. 2.—Showing basket and support.

The steam oven is used in drying precipitates which have been separated by micro-filtration, either at 100° C. (e.g., calcium oxalate) or at room temperature (e.g., magnesium ammonium phosphate). The micro beaker containing the filter stick is placed in the wire basket, and the stick is connected by a short length of rubber tubing to the narrowed end of the tube *a*. An advantage of this design over the Pichler drying tube is that the manipulation is performed before the beaker is placed into the oven. The apparatus is then assembled and gentle suction is applied to the outer end of *a*. The inlet, *c*, may be closed by a length of capillary tubing drawn out to a very fine jet, when, with steam passing through the jacket, drying is rapidly effected in vacuo. Alternatively, *c* may be connected by a length of flexible rubber tubing to a tower containing anhydrous calcium chloride, or, for ammonium magnesium phosphate precipitates, hydrated calcium chloride. The air entering at *c*, should be filtered through a cotton wool plug; this is particularly important if the air is first dried over calcined calcium chloride as, otherwise, minute fragments of calcium chloride dust may be carried in which, being deliquescent, will appreciably affect the weight of the micro apparatus.

The apparatus can with advantage replace the micro steam bath for most purposes. It may, for example, be used for the evaporation of a liquid contained in a micro beaker. In this case a length of fine glass tubing is connected to the narrowed end of *a*, so that its lower end is some 5 mm. from the surface of the liquid. Gentle suction is applied at *c*, and air is drawn through a cotton wool plug from a calcium chloride tower into *a*, to impinge on the liquid surface.

Care must be taken that the velocity of the air stream is not too great; the jet aperture should be 1–2 mm. in bore. (Loss due to splashing is a not uncommon source of error in quantitative micro analyses which require an evaporation procedure). The application of this micro oven to the treatment of precipitates or liquids in an inert atmosphere will readily be appreciated.

The apparatus was made in stout-walled Pyrex glass by The Laboratory Glassblowers Co., Wembley.

Polarographic Determination of Lead in Aluminium Alloys

By William Stross

A rapid and simple polarographic method for the determination of lead in aluminium alloys based on work by Kolthoff and Matsuyama,[4] is described which is applicable to lead contents from less than 0·05 to approximately 3%. The metal is attacked with hydrochloric acid; the interference of tin is prevented by oxidation, that of iron by reduction at controlled pH, and copper is precipitated.*

IN the vast majority of aluminium alloys lead occurs only as an undesirable impurity. The specifications of many alloys define the maximum permitted content as 0·05%; in others the sum of all impurities (or of several impurities, including the lead) should not exceed 0·1–0·2%, which may further decrease the permissible quantity of lead, dependent upon the quantities of the other elements present.

Occasionally higher lead contents are found as impurities in secondary metal and for some commercial (though rarer) alloys lead is specified as a constituent in quantities from 0·8–2%.

A routine method for lead determination should, therefore, be equally well applicable to all alloys within the range from approximately 0·03–3%, and, as so many specifications contain a limit for lead, the method should also be fairly rapid. The well-known methods, however, are so far from fulfilling these requirements that, in many laboratories, the testing for lead is done almost exclusively by spectrographic methods and wet methods are used comparatively rarely, mainly for confirmation.

No straightforward colorimetric (photometric) method is known to the author which would be comparable for accuracy, speed, useful range and simplicity to the now well-established photometric procedures for determining copper, iron, nickel, silicon, manganese, magnesium and titanium.

Colorimetric methods have been proposed, based either on the brown coloration of dilute lead solutions in presence of sulphuretted hydrogen[1a,c] (requiring the preliminary isolation of the lead) or on the colour reaction with dithizone[2a,b].

These methods are sufficiently sensitive to test for very small quantities of lead[1,2,3], but they have various disadvantages: They are rather long-winded and delicate, being mostly based on visual comparison with comparatively unstable standard solutions, and they are not easily applicable to lead contents well above 0·2%.

As lead gives a well-defined "wave" in many media a polarographic method could be expected to offer good prospects for aluminium alloys, particularly as polarographic methods for lead determination have been developed successfully for a variety of ores, metals and alloys (e.g., zinc and its alloys, magnesium alloys, brasses and bronzes).

Several polarographic methods for the determination of lead in aluminium alloys have been published. Some require comparatively complicated extractions by dithizone and organic solvents[1b,c] and others[3] are only applicable where the alloy does not contain much more copper and iron than lead—thus only applicable to a small minority of alloys.

A more recent polarographic method by Kolthoff and Matsuyama[4] is not subject to such disadvantages. This method forms part of a scheme in which an alloy is completely taken into solution by attacking it with just the theoretical amount of sodium hydroxide and acidifying with just the theoretical amount of nitric acid, making up to volume and using different aliquots of this solution for the polarographic determination of lead, zinc, copper, iron and nickel. Of the variety of theoretically interesting methods proposed for these five elements in that paper, only the method for lead seems to be of practical interest for purposes of production control.

For the determination of iron, copper and nickel it seems obvious that the modern photometric procedure[5] offers greater speed, accuracy and simplicity, particularly as these three elements can also be determined from one and the same weighing by the photometric method; for the zinc it has been recently discussed by the author in these pages[6] what the requirements for a polarographic routine method are, and the two zinc methods proposed by Kolthoff and Matsuyama clearly do not satisfy these requirements.

Kolthoff and Matsuyama's lead method follows the following outline: First, the pH of the aliquot used for the lead determination is adjusted by careful addition of 1 N sodium hydroxide solution to the colour change of thymol blue from red to orange; this is followed by the addition of one further ml of the N sodium hydroxide, then of 0·5 ml each of the hydroxylamine and potassium thiocyanate solutions, to precipitate copper and reduce iron.

The procedure established by R. Strubl[7] for the polarographic determination of lead, uranium and other elements in iron alloys and used by the British Aluminium Company for the polarographic determination of antimony[8] was thus adapted by Kolthoff and Matsuyama to aluminium alloys. It was found to work

* This was the highest range investigated so far, but there is no reason to assume that higher contents should present any particular difficulty.

1 Analysis of Aluminium and its Alloys, The British Aluminium Co., Ltd., Publication No. 399, 1941. (*a*) p. 45; (*b*) p. 184; (*c*) Pub. No. 405, 1947, p.91.

2(a) See e.g., Beaumont, *Metallurgia*, 1944, 217, or Sandell, E. B., Colorimetric Determination of Traces of Metals, Interscience Publishers, New York, 1944.

2(b) Since this paper went to print, the publication 405, of British Aluminium Co. Ltd. was issued, giving on page 92 a new dithizone method.

3 Nickelson, A. S., *The Analyst*, 1946, **71**, 58.

4 Kolthoff, I. M. and Matsuyama, G., *Ind. and Eng. Chem., Anal. Ed.*, 1945, **17**, 615.

5a Haywood, F. W. and Wood, A. A. R., Metallurgical Analysis, Hilger, Ltd., London, 1944.

5b Stross, W., *Metallurgia*, October, 1945, 257.

5c Phillips, D. E. and Edwards, L. L., *Metal Industry*, 1945, **66**, 409.

6 Stross, W., *Metallurgia*, 1947, **36**, 163 and 223.

7 Strubl, R., Collection of Czech Chemical Communications, 1938, **10**, 466.

8 Analysis of Aluminium and its Alloys, Spectrochemical and Polarographic Methods, The British Aluminium Co., Pub. No. 401, 1943; (a) p. 76; (b) p. 78.

well on the whole, but if lead only is to be determined, it is unnecessary first to prepare a "universal solution." It was also found tedious to adjust the pH of each sample individually; during this adjustment, some aluminium hydroxide is precipitated, due to local alkalinity, even when the solution is shaken vigorously, and this precipitate only redissolves with difficulty. In our experience some operators do not find it easy to discern the desired colour change with any degree of accuracy, and the pH of these solutions, when determined by glass electrode measurements, was therefore found to differ rather widely. The use of only just the theoretical amount of sodium hydroxide and of nitric acid make the attack and acidification very slow, particularly on alloys rich in silicon (5% and more).

The following modified procedure, though in principle adopting the method established by Strubl and Kolthoff and Matsuyama, is thought to achieve a considerable gain in speed and simplicity, and has been found reliable and easy to operate on a routine scale.

Reagents and Apparatus Required

Hydrochloric acid, 5 N.

Sodium carbonate solution, 1 N.

Hydroxylamine hydrochloride solution, 2 M (13·9 g of the solid, preferably of A.R. grade, made up to 100 ml with water).

Potassium thiocyanate solution, 2 M (19·4 g of the solid, made up to 100 ml with water).

Potassium chlorate, saturated aqueous solution.

Gelatine, 0·25% solution (dissolve 0·5 g in approximately 150 ml of water by warming and stirring, cool, make up to 200 ml and add one or two pea-sized crystals of thymol to prevent growth of micro-organisms; shake well at first to saturate the solution with the thymol before microbes can develop).

Standard lead solution with 1 mg of lead per ml, prepared from "A.R." grade lead nitrate.

Twenty-five ml measuring vessels; "heavy weight" boiling tubes, 6 × 1 in., accurately calibrated at 25 ml are very suitable.

Procedure: Attack a 200 mg sample in the calibrated tubes with 5 ml of the 5 N hydrochloric acid. When the reaction calms down,* wash down sparingly and place the tube into water at approximately 80° C. When the reaction is complete, add 0·4 ml of the potassium chlorate solution, stir well and replace in the hot water for a few minutes, stirring occasionally. Cool slightly and add 8 ml ot the sodium carbonate solution. Shake or stir until any precipitated aluminium hydroxide has redissolved. Add, in order, 0·5 ml each of the hydroxylamine and of the thiocyanate solution, shaking during the additions; any copper present is precipitated and the ferric thiocyanate is quickly reduced with disappearance of the red colour, indicating that the reduction is complete.

Add 1 ml of the gelatine solution and make up to the 25 ml mark. Mix and centrifuge, or filter through a Whatman No. 40 or similar close-textured filter. Any opalescence of the filtrate may be disregarded.

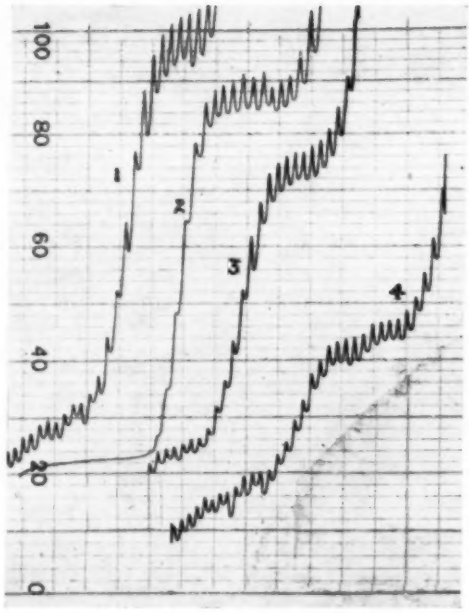

Fig. 1
Polarograms of solutions obtained by the described technique.

From left to right:
1. Approximately 0·11% Pb, sensitivity 0·5 (100 divisions = 0·5 micro-amps.)
2. Approximately 1·1% Pb, sensitivity 4.
3. Approximately 0·09% Pb, sensitivity 0·5.
4. Approximately 0·035% Pb, sensitivity 0·5.
Some compensating current and zero adjustment was used in all cases and the recording was started at different potentials, in order to bring the graphs close together for reasons of space economy.
Silver wire anode. Only one accumulator connected to main potentiometer.

Expel the oxygen by passing an inert gas and record the polarogram, using one accumulator only, from approximately 0·4–1 volt.† Sensitivity, 0·5‡ covers the range up to about 0·15–0·2% of lead and the maximum content investigated so far by this technique was about 3%, using sensitivity 10.

Fig. 1 is an illustration of the type of records obtained. The time required is about 30 minutes, the average time is, however, considerably reduced if large batches are processed simultaneously so that one operator can easily carry out 12 determinations in 2–2½ hours.

Calibration is achieved by treating standard samples of known content in a similar way as the sample under test. If a suitable standard alloy is not available, known quantities of standard lead solution can be added during the processing to lead-free samples or to samples of known low lead content.

For the range of less than approximately 0·2% of lead the standard should have a copper content comparable to that of the sample under test as some lead tends to be co-precipitated with the copper. This applies to the original technique of Kolthoff as well as to the above modification. Whilst this loss of lead is smaller in presence of very low copper quantities—say 0·1%—than with medium ones—say 1%—it does not increase substantially with further increase of the copper content; very

* Cooling is generally not required, except with very finely divided samples—e.g., fine powders.

† This applies to the Tinsley pen recording polarograph, with which normally two accumulators are used; one accumulator is, however, preferable in this medium for lead determination, particularly if nickel or cadmium are present. If only one-h. lf of the normal potential is applied to the main potentiometer the voltage values on the scale of the instrument must be divided by two to indicate the true potential applied; the above figures 0·4-1 volt are the apparent values, as indicated by the pointer.

‡ This applies likewise to the Tinsley instrument. Sensitivity 0·5 means that 0·5 micro-amps correspond to a deflection of the recorder over the whole width of the paper—i.e., 100 divisions.

TABLE I.—COMPARISON OF RESULTS

Type of Alloy	Standard sample	Per cent. lead found by: Author (polarographic)	Independent laboratories A	B	C	D	E
"Y"	LMFA*	0·08	0·06	0·07	0·07	0·075	0·07
D.T.D. 424 ..	ALAR	0·03	0·01	T.+	0·02	<0·01	T.+
D.T.D. 324 ..	„	0·06	0·07	0·07	0·07	0·06	0·07
D.T.D. 133C.	„	0·035	0·02	0·02	0·02	0·01	0·01
LAC 113B ..	„	0·10	0·10	0·08	0·08	0·09	0·09
LAC 10 ..	„	0·03	0·01	0·02	0·02	0·03	0·02
2 L 33	„	0·03	—	0·01	—	0·01	0·01
British Chemical Standard Aluminium Alloy "A"	Standard Alloy	1·52	1·54 1·56	1·55 1·52	1·58 1·51	1·53 1·42	1·55† 1·30

* The figure returned by the L.M.F.A. (Light Metal Founders' Association) as the result of careful analysis by a number of laboratories (not identical with laboratories A–E) is 0·07 ± 0·01.

† The 10 figures given for the British Chemical Standard are taken from the testing certificate, and they originate from different laboratories than those responsible for the figures on the other alloys. T = Trace.

low lead contents—e.g., 0·02% and less—in presence of large copper contents—e.g., 5–10%—can, however, not be determined reliably by this method. It is worth noticing that in spite of this source of error the results of the described polarographic procedure on alloys with low lead contents tend to be slightly higher than those of the traditional methods, as is born out by Table I. This table shows the results of a number of independent laboratories, using different methods, on standard samples. Each figure is the average of several tests.

Notes on the Method

1. A very uniform pH of the final solutions is reached without having to adjust the reaction of each sample individually if the following simple precautions are observed. During the attack a temperature of about 80° C. should not be exceeded and the tubes not immersed deeper in the hot water than the height of the liquid in the tubes; if then the period of heating is not unnecessarily extended, the loss of acid by evaporation is negligible.

2. Sodium carbonate is preferred to sodium hydroxide for adjusting the acidity to the pH at which the reduction of iron and the precipitation of copper proceed smoothly at room temperature (i.e., a pH not below 2·5) as any precipitated aluminium hydroxide redissolves much more easily if carbonate is used for neutralising.

3. It has often been stated that polarographic records can be taken without removing precipitates formed during the processing. It is, however, felt that in most cases, and particularly in that of the method under discussion, the small trouble of filtering or centrifuging the solutions is offset by the better definition of the polarographic waves. The removal of the precipitate is also recommended in view of the firm adherence of the cuprous thiocyanate precipitate to the electrodes and the walls of the cells, necessitating tedious cleaning. At the pH of the final solutions—pH 3·2 approximately—no loss of lead by adsorption on the filter paper occurs whilst this risk is very serious in alkaline solution.

4. The solubility of lead in hydrochloric acid is quite sufficient to guarantee complete extraction under the conditions described.

5. If the alloy contains more than approximately 1·5% silicon, this element is obviously not dissolved by this procedure and the solutions will remain dark. This does not seem to interfere with the extraction of the lead, and the silicon is eventually removed with the copper precipitate. Experience on low silicon alloys quickly shows how much stirring and warming is required after the addition of potassium chlorate to dissolve the copper completely. It does, however, not matter if some copper remains undissolved as the hydrochloric acid easily extracts the lead from the copper; the main purpose of the addition of potassium chlorate is the oxidation of any tin present as the waves of lead and stannous tin coalesce whilst stannic tin does not give any wave at all under the conditions chosen. Even tin contents of several per cent.—thus much more than is normally encountered in aluminium alloys—do not interfere.

6. The method can be used as a micro or semi-micro method without any substantial change of technique and without loss in accuracy. As a volume of 1–2 ml is ample for polarographic purposes, it is quite easy to reduce the quantities of sample and reagents to one-tenth to one-twentieth of the quantities specified, thus taking a 10–20 mg sample of alloys with less than approximately 0·15% of lead. Still smaller weighings can be used if the lead content is higher, without further reducing the final volume.

7. The silver wire anode recommended by Lingane[9] can be used to great advantage—i.e., with saving in time and mercury, as discussed recently by the author.[6]

8. In analogy to the good results obtained on copper-base alloys by other authors[10, 11] attempts have also been made to use cyanide (at alkaline reaction) for suppressing the interference of copper. These experiments were, however, unsuccessful.

Acknowledgment: The author wishes to thank the directors of Messrs. International Alloys, Ltd., in whose laboratories these investigations were undertaken, for permission to publish this paper.

9 Lingane, J. J., *Ind. and Eng. Chem., Anal. Ed.*, 1944, **16**, 329.
10 Milner, G. W. C., *Analyst*, 1945, 250.
11 Spálenka, M., *Z.analyt. Chem.*, 1943, **126**, 49.

British Council's Bursary Schemes

THE British Council has inaugurated a scheme for the award of Short Term Bursaries to candidates from overseas to enable them to see something of British industrial technique and machinery. The majority of the candidates will be technical workers, and each Bursary will cover travel to and from the United Kingdom and will include a maintenance grant during the three or four months they will spend in this country.

Examples of the trades which have so far been included are: Water engineer, teacher of the blind, tractor engineer, electrical fitter, road construction engineer, wagon shop and carriage foreman, youth club leader and librarian.

The New Osram Catalogue

BACK again after an enforced absence of eight years, the new Osram lamp catalogue once again supplies the answers for all who buy or sell quantities of lamps There have, of course, been many changes since the last catalogue was published, and fluorescent lamps are featured for the first time.

Many types of lamps are no longer listed and some new ones are making their initial appearances. Apart from the fluorescent lamps, the latter include the 250-watt infra red lamp with internal reflector, the 60-watt metal filament radiant heat lamp and the British pre-focus bulb. A list of Elma lamp classifications is included, together with a useful ready reckoner. The catalogue contains 52 pages and is extremely well illustrated.

Reviews of Current Literature

Argonarc Welding

CERTAIN investigations on the Argonarc welding of magnesium alloys carried out by members of the British Welding Research Association, L.M.3 Committee on the Fusion Welding of Magnesium-rich Alloys are described in this Report which comprises four papers. These were first presented by the authors to the British Welding Research Association Symposium on Light Alloy Welding held in October, last year, and are published in this form in response to a widespread request from the industry for detailed and factual data regarding the welding of magnesium alloys by Argonarc.

The papers included are: "Argonarc Welding of Magnesium-rich Alloys" by R. E. Doré, L. C. Percival and R. R. Sillifant; "Argonarc Welding of Magnesium Alloys at High Duty Alloys Ltd." by E. J. Grimwood; "Some Notes on an Investigation of the Hand Method of Argonarc Welding as Applied to Magnesium-base Alloys" by F. A. Fox; and Argonarc Welding of Magnesium Alloys at Metropolitan-Vickers Electrical Co. Ltd. by I. H. Hogg. In addition, the Report contains an appendix illustrating types of welded joint which are now possible as a result of the introduction of the Argonarc technique.

The results of early experimental work are summarised in the papers by Grimwood, Fox and Hogg, using equipment initially designed for welding with a helium-shielded arc. A series of later investigations on Argonarc welding are described in the paper by Doré, Percival and Sillifant. These latter investigations were carried out during the past few years and provide detailed and factual data of the welding technique and procedure, including the use of high frequency currency for stabilising the arc. Although the work is mainly related to magnesium alloys, other metals, including stainless steel, are also dealt with.

In presenting this Report the Committee appreciate that true industrial development of a process only begins with industrial application. They would, therefore, welcome reports on problems arising during industrial application of Argonarc welding in order that industrial experience can be fully integrated with the further work on this process.

Special Report No. LM3/28, published by the British Welding Research Association, 29, Park Crescent, London, W.1 (price 7s. 6d.).

Magnetic Powders

IT seems that powder metallurgists in France have achieved considerable success in the manufacture of permanent magnet materials from very fine powders made by various unorthodox methods. Iron powder made by the Raney method of carbonyl iron powder made by bubbling hydrogen through liquid iron carbonyl has an average particle size of only 0·1 micron. Without alloying, such powder is pressed cold and does not require sintering or heat treatment, giving coercivities up to 450 oersteds.

The powder metallurgy technique is also finding new applications in the manufacture of high temperature alloys. Further details can be found in the "Metal Powder Report," a monthly abstracts journal published by Powder Metallurgy Ltd., Commonwealth House, 1–19, New Oxford Street, W.C.1, annual subscription rate £3 7s. 6d.

New Metallurgical Process

A DEVELOPMENT of considerable importance to the metal industry is the recently marketed portable "Deminrolit" plant by Permutit, designed to produce reasonable quantities of water of distilled quality "in situ." This equipment has great possibilities in connection with metallurgical processes such as anodising, electro-plating, etc., washing of powers, etc., where solutions must be of the highest order of purity for the most consistent and effective results.

This portable model is the logical development of a process by which dissolved salts can be removed from a water supply at atmospheric temperature without the use of heat, known as the "Deminrolit" process.

Wherever the need arises, as it does quite often, for an equivalent of distilled water, this lightweight plant can supply up to 75 gallons between each regeneration, at a fraction of the cost of commercially distilled water. The water is demineralised by a chemical process known as ion exchange, and no heat or power is required to effect this. It is claimed to be extremely simple in operation, the equipment requiring only to be regenerated periodically as with the normal type of base-exchange water softener installation. Regeneration is effected by hydro-chloric acid and sodium carbonate solutions prepared in a collapsible plastic tank. The process or regeneration is fool-proof since an electric tester is attached to the plant to indicate when regeneration is required and by merely turning a knob on the right hand side of the indicator, the full regeneration cycle is accomplished. This plant, which weighs only 56 lbs., would be extremely useful to laboratories, or in fact for any industrial process calling for only reasonable quantities of water of distilled quality. Especially useful in this connection would be its use as a "pilot" plant to test new processes on a semi-production basis.

British Council Scholarships

THE British Council has awarded scholarships for 1947–8 to 256 graduates or others of like status from 62 countries, including the Dominions and Colonies, to enable them to undertake a year's specialist study in the United Kingdom. In addition, 106 British Council scholars have had their scholarships extended for a further year.

For the first time, scholarships have been awarded to candidates from Burma, Kenya, Uganda, Northern Rhodesia, Malayan Union and Singapore, Nicaragua and Saudi Arabia. The majority of the 362 scholarship holders are studying in British Universities or University colleges widely distributed throughout Britain and the subjects of study cover a wide range.

MESSRS. THOMAS SUMMERSON AND SONS, LTD., have announced that, as from October 1st, 1947, the two sides of their activities will be conducted as separate entities. The railway engineering, siding installation, and consultative side of the business will continue to be known as Thomas Summerson and Sons, Ltd., while the foundries' side covering steel foundry, iron foundry, machine shops and metallurgical part of the business will be known as Summerson's Foundries, Ltd. This change has been made to facilitate administration and encourage further specialisation in the Companies' products.

Mechanical Testing of Materials by the Torsion Method

By Ya. B. Fridman

EACH of the four basic methods of loading, tension, compression, bend, and torsion, has its own special peculiarities which are shown most clearly in the case of plastic materials at sufficiently great degrees of deformation.

These peculiarities relate to: (1) The formation of a neck in tension tests, and consequently the development of a non-uniform and volume stress state; (2) the existence of friction at the compression plates in compression tests; (3) the impossibility in the case of bend and compression tests, of fracturing a plastic material which shows a reduction in area in a tensile test of more than 50%; and (4) the non-uniformity in distribution of stress and strain which necessarily occurs with bend and torsion tests.

For mechanical testing it would be desirable to choose the simplest form of test giving results which did not suffer from too great a complexity of interpretation. The preference has, hitherto, been almost exclusively accorded to tensile testing, but developments in recent years in the realm of mechanics of materials are tending to show that this fixation is unsound. It appears, however, that whilst attention has been paid to the fields of applicability of bend and compression testing, that of torsion has been almost completely and quite unfairly ignored.

Even the most plastic material may be easily broken by means of torsion, as in the case of tension. But with torsion, there is the important fact that the form of the sample suffers practically no change however great is the strain. This makes possible an accurate evaluation of stress and strain. With a tensile test sample, the stresses and strains in the neck of the pulled sample are unknown, since up to the present time there has been no accurate method of quantitative evaluation of stresses and strains in a neck or notch when the plastic deformation is considerable, although approximate calculations have been made by Siebel, by Bridgman, and by Davidenkov.

Furthermore, it is very important in many cases to construct complete diagrams of deformation at high and low temperatures. The use of the tensile method, accompanied as it is by changes, during the loading, in the diameter of the sample at the neck, is extremely inconvenient. This is particularly so at high temperatures, for the contact of the measuring instrument produces scratches and depressions on the surface of the neck of the sample, and increases still further the complexity of evaluating the results.

For these reasons there have been recorded hardly any true stress curves obtained experimentally at temperatures other than room temperature. The two-load method of MacGregor does not solve the problem and it is approximate in that it assumes the tension curve to be linear.

In contrast with tension, torsion is easily carried out both at high and low temperatures without contact between the surface of the sample and a measuring instrument, at least in the case of measurement of great deformations, not requiring the use of an ultra-sensitive tensometer.

The inaccuracies associated with the measurement of load when the deformation becomes localised during a tensile test do not arise with torsion, since in the latter case, the turning moment is increasing continuously or is constant right up to the instant of fracture.

Calculation of deformation during torsion is made by means of Nadai's formula:

$$g_{max} = \log_e \left(1 + \gamma_{max}^2/2 + \gamma\sqrt{1 + \gamma_{max}^2/4}\right)$$

where g_{max} is the true shear, and γ_{max} is the conditional shear. For a sample of radius r and length l, in which the torsion angle over the whole working length l is ϕ, we have

$$\gamma_{max} = \theta \times r \text{ and } \theta = \phi/l$$

Calculation of shear stress is made by means of the formula of Ludwig-Karman:

$$t_{max} = \frac{1}{2\pi r^3}\left(3M_t + \theta\frac{dM_t}{d\theta}\right)$$

where M_t is the twisting moment, and $\frac{dM_t}{d\theta}$ is a derivative which is determined graphically. This graphical determination may be carried out by drawing tangents with the assistance of a ruler fitted with a mirror as indicated in Fig. 1.

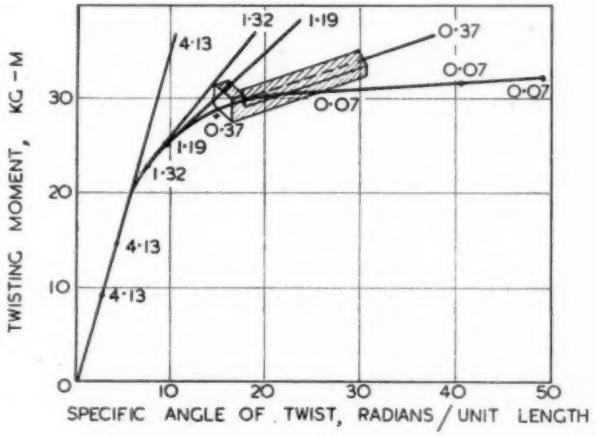

Fig. 1.—Type of curve obtained in torsion tests.

From a paper in the Russian journal, *Zavod. Lab.*, 1945, 11 (9), 852.

1 A. Nadai, *J. Applied Phys.*, 1937, 8, 205.
2 P. Ludwig and R. Scheu, *Stahl u. Eisen*, 1925, 45, 373.
3. P. Ludwig, *Elem. der technologischen Mechanik*, 1909, p. 41.

TORSION TESTS ON A SAMPLE OF TOOL STEEL, QUENCHED IN OIL FROM 880°. MACHINE—600 Kg. AMSLER.

Twisting Moment, M_t, kg.-m.	Angles of Rotation $\phi_1°$	Angles of Rotation $\phi_2°$	Angle of Twist $\phi°$	Angle of Twist in radians per unit length ϕ	$d\,M_t / d\,\theta$	Shear stress $t_{max.}$, kg./sq.mm.	Relative shear strain $\gamma_{max.}$ %	True shear strain, H, %	Octahedral shear stress, t_n, kg./sq.mm.	Octahedral shear strain, g_n, %
1	2·5	1	1·5	0·47	4·3	6·4	0·235	0·235	5·2	0·192
2	4	1	3	0·95	4·3	13·1	0·475	0·475	10·7	0·38
3	6	2	4	1·27	4·3	18·3	0·635	0·635	14·9	0·52

If octahedral curves (t_n, g_n) are required, the values of t_n and g_n are calculated from the formulae, $t_n = 0{\cdot}817\ t_{max}$, and $g_n = 0{\cdot}817\ g_{max}$. The system of recording, and the whole process of calculation are made clear by the Table.

With tension, compression, or bend, as deformation proceeds, the crystallographic slip-planes change their orientation relative to the surfaces of maximum shear stresses, and the observed total plasticity is a complex integrated characteristic. With torsion on the other hand, the planes perpendicular to the axis of the rod, do not turn at all.

Ludwig, as long ago as 1909, pointed out the neglect of torsion as a test method. He said that it would often give not only a more complete, but a clearer and purer picture of the change of state of a metal during deformation than tensile testing.

An additional advantage of the torsion method is the sharp distinction it makes between the two types of failure, shear and rupture. With torsion, these occur on differently orientated planes, whilst with tension, it is still not known in many cases whether the failure should be considered as shear or rupture.

In many materials that are brittle under tensile loading, e.g., low-tempered constructional and tool steels, torsion reveals the considerable plasticity that these materials possess under a favourable stress state. In these cases, torsion is the only possible satisfactory testing method.

Thus, the use of torsion testing may be recommended in all cases where it is important to determine mechanical properties of materials under conditions of considerable deformation, e.g., plasticity, viscosity, work-hardening, resistance to shear, etc., whether at room temperature or at high or low temperatures. When, however, it is necessary to employ less gentle conditions of loading, e.g., to reveal resistance to rupture, then tension or bend should be used.

The torsion method together with the tension method ought to be adopted as the basic methods of static testing for the study of the effects of composition and treatment on the properties of ferrous and non-ferrous metals and alloys.

Die-Casting Trends

By Fred C. Ziesenheim

PRESENT die-casting machines are of two types: (1) Submerged plunger injection machines for low-melting-point alloys (lead, tin and zinc) requiring temperatures up to 800° F. or more; and (2) cold-chamber injection machines for the high-pressure casting of high-melting-point alloys (aluminium, magnesium and brass), 1,100° F to 1,800° F.

Apart from the injection systems, the functions and structure of the machines are similar, so that either class of machines can be readily converted from one type to the other. The Hydraulic Press Manufacturing Co. design die-casting machines in both types of injection systems in rated die-clamping tonnages of 150 ton and 400 ton. A 1,000-ton cold-chamber machine has also been built.

Submerged plunger injection machines upon manual initiation can automatically complete each casting cycle, which includes the casting operation, removal of cores by cams or hydraulic cylinders, and the ejection of the casting by bumper bars or by hydraulic cylinder. Cycles may be fast—up to 350 or more "shots" per hour.

Cold-chamber machines require the closing of the die, then the hand-ladling of the molten material into the cold chamber, after which the operator touches a foot pedal and the automatic cycle of metal injection, chilling time, core pulling, and parts ejection takes place. Cycles may range from 60 to 120 or more shots per hour, depending upon the weight of the material being hand-ladled.

Modern machine design has made considerable progress in eliminating porosity, which has meant increased strength of die-cast parts. There are two sources of porosity in castings—shrinkage voids and entrapped air and gases. Effort is made in die casting to overcome shrinkage voids by applying pressure on the casting as it chills in the die. Likewise, entrapped air or gases which cannot be avoided are minimised and compressed in volume by pressure applied on the casting as it chills in the die, preferably to the point where the porosity is not discernible by X-ray. Machines then must be capable of applying and holding high pressure within the die cavities.

The trend toward larger zinc die castings, noted before the war, has been reversed. Lighter castings are being made which are assembled into larger-appearing units.

One of the largest aluminium die castings made has been an air-cooled engine cylinder and crankcase unit. The air-cooling fins are thin, long, and spaced fairly close together. The casting weighs 15 lb. as cast and 13 lb. finished. The dies weighs 14 tons and took 50 men one year to build.

Die-cast air-cooled engine blocks for aircraft and automotive use are said to be entirely feasible and practical. One motor manufacturer has announced a 2-cycle, opposed-piston, air-cooled engine of 125 h.p., weighing 150 lb. It consists of five major aluminium die castings and six aluminum pistons and other elements.

Large automobile-body panels and doors have also been considered in both aluminium and magnesium die castings. Another projected use for aluminium die castings is the master and service cylinders of hydraulic brake systems. Such castings have been used in the aircraft field for years. Other parts originally switched to die castings because of shortages of iron are now used because they are reported to be better and cheaper. Fluid-drive couplings for automotive use having airfoil blade sections (which will reduce slippage from 10 to 20%) are being developed for production as die castings. Likewise, more efficient car-heater fans are being produced.

Electric-motor manufacturers are turning to die casting for housings, end bells, and the like, as well as for help

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in improving actual working parts. Copper rotor bars, separate conductor rings, and stamped-steel fan blades have been eliminated in rotors by die casting all of these elements integrally in high-purity aluminium. The integral-die-cast aluminium rotor provides a light, long-life assembly with no subelements to come loose and cause trouble.

The advantage of die casting over the usual "dunking" (or permanent-mould) method of casting aluminium motor rotors is not only a higher output per man-hour but a much lower reject ratio. This is due again to the application of high final injection pressure in the casting cycle.

Because of the low rejection factor, large rotors are being considered for die casting by many manufacturers. It is difficult to salvage rejects but it has to be done to conserve the silicon-steel laminations. Saving copper and eliminating its high cost is also a factor. The elimination by die casting of some other structural elements used in motors is also being considered. The building industry is using more zinc die-cast hardware to meet shortages and cut costs. Gas and electric meters and even electric conduits are now made more economically in aluminium die castings.

The method and equipment used for brass die casting can be the same as for the cold-chamber die casting of aluminium. However, due to the metal temperature of 1,800° F. as compared with 1,200° F. for aluminium it is obvious that die life will be considerably less. Die life may range from less than 10,000 shots to as many as 100,000 shots. The most successful brass die castings have been those involving thin-walled sections. However, some large brass die castings, up to 12 and 15 lb. have been made successfully.

An important need for the efficient cold-chamber die-casting of large heavy castings is a method for automatically ladling the molten material into the cold-chamber injection system.

A proposed method under development is the discharge at uniform rate for a given period of time of hot metal from an electric induction furnace, by utilising the "pinch pressure" or magnetic flow movement of the hot metal through an orifice or tube about the electric transformer. It is now being adapted to permanent-mould practice where the moulds can be transported past the furnace.

Nitrided Steel Hot Formed After Heat Treatment

By Jack Frazier

UNDER the stress of war many problems were solved in days that in less strenuous times would have involved as many months. In many cases the theory on which these solutions rested were not developed and part of the possible value of the work was lost. One such development was the evolution of a new series of operations upon a nitriding steel. The results obtained contradict several of the accepted ideas about processing a nitriding steel, and no theory has been developed to explain why these results were obtained.

It was decided to use nitrided steel for the sleeve valves of an internal combustion engine so as to have the necessary hardness in this engine part for long and hard service. The steels designated as Nitralloy 135 (Type G) and Nitralloy 125 (Type H) were selected for tests. Although both were suitable, it was finally decided to use Type H. These steels have the following compositions: —

Type H		Constituent		Type G
0·20–0·30	..	Carbon	..	0·30–0·40
0·40–0·60	..	Manganese	..	0·40–0·60
0·30 max.	..	Silicon	..	0·30 max.
0·90–1·40	..	Chromium	..	0·90–1·40
0·90–1·40	..	Aluminium	..	0·90–1·40
0·15–0·25	..	Molybdenum	..	0·15–0·25

A case depth of 0·008 in. was fixed upon so that inside and outside finishing of the valve would leave a case 0·006 in. thick. The design required a thickness of 0·0455 in. in the valve sleeve, with a tolerance of plus or minus 0·005 in. The first move to assure a high rate of production upon the sleeves was made by the steel makers agreeing to produce a special strip, with a grind pass after annealing and just before the final cold roll to 0·050 in. This produced a strip of Type H Nitralloy steel, down to size, and with no decarburised zone, so that it was ready for immediate forming operations.

In arranging the sequence of operations, several of the accepted concepts about nitriding raised an obstacle. A desirable sequence would have been as follows: (1) blank; (2) cold form; (3) nitride; (4) finish hot form; (5) inside hone; (6) outside finish; (7) finish condition. This would have the advantage of giving the sleeves their final form after all heat treatments, so that distortion would be eliminated. A hot finish forming operation would be satisfactory upon the hardened pieces if final hardness could be held to the required 65 to 67 Rockwell C.

In view of the generally accepted prohibition against heating of nitrided parts above 1,200° F., this sequence seemed impossible. Cold forming of the nitrided parts was out of the question, and temperatures considerably above 1,200° F. would be required to hot form the sleeves without danger of cracking. An intensive study of the nitriding process and the final hot form was begun, in the hope of finding some combination that would give a satisfactory result.

The solution was finally reached in a combined forming and pressure quenching operation, for which a special die was developed. Some interesting facts about the nitriding process were learned at the same time. One of these was that, for this work, a sorbitising process before nitriding was not necessary. Another was that a completely satisfactory case could be produced in considerably less than the time usually recommended, despite the high ratio of area to weight in these sleeves. Sorbitising, or any similar protracted treatment at elevated temperatures, was not feasible after centres on the valve sleeve were established in the blanking and cold forming operations.

The blanking operation presented no problem. A die was made to cut the shape of the valve, and to punch the holes for the ports and for the rivets at the same time. After making approximately a thousand check tests, it was determined that metal movement which occurred during hot forming was consistent enough to make allowance for any such changes in the blanking die. Cold forming was also a routine procedure, accomplished in two steps. A first operation gave the flat blank a partial form, and a second step completed the semi-cylindrical shape. It was found that a slight overforming here was advantageous in the final forming operation. The partial forming helped to maintain the centre line of the valve, and the overforming in the second step largely

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compensated for the slight springback during nitriding.

Nitriding was done in Leeds Northrup furnaces, with the temperature closely held at 975 to 980° F., the ammonia at 30% dissociation, and with the time at first about 15 hr. After a little experimentation, it was found that an effective case depth of 0·006 to 0·0008 in. was obtained in 9 hr. with the H alloy and in 4 hr. with the G alloy. Two hours were allowed for heating and cooling before and after actual nitriding. Rockwell hardnesses, as converted from the superficial scale, were 68° to 70° C.

Closely related to the nitriding was the problem of the final hot forming. It was required to heat the sleeves to a temperature high enough to permit their being formed without any danger of cracking, and without any significant loss of hardness in the pieces. The solution finally reached required close control of temperature, pressure, and time, and involved the use of a hot forming die developed to quench as it formed.

The sleeves were heated in a controlled atmosphere furnace to 1,950° F. with a maximum soaking time of 3 min. They were then removed, one at a time, and each was immediately placed in the lower male half of a forming die, 30 tons pressure applied by the upper female half, and the pressure was maintained for 20 sec. The sleeve was then removed, checked on a gauge, and passed to the surfacing operations. Hardness readings upon the finished pieces all fell within the range that, converted to Rockwell C, was required, i.e., 65 to 67.

The rate of heat withdrawal was critical, and all factors had to be closely controlled in view of the thinness of the metal involved. The dies were water-cooled. Prompt handling of the sleeves as they left the furnace eliminated the air cooling that is always a danger with light work, so that the cooling was started from a temperature quite close to furnace heat. The design of the die provided against uneven cooling, or pre-cooling of the work before the closing of the dies, by providing disappearing supports about 2 in. long at each side of the die. These supports held the sleeve out of contact with the cooled portion of the die, but were forced down as the two halves of the die closed.

It was found that the 20-sec. period during which the dies remained in the closed position must be held very accurately. Pressure was critical also. Thirty tons gave perfect results. Decreasing the die pressure to 20 tons caused the sleeve to be under-formed, while at 35 tons cracking began to develop. The temperature of 1,950° F. was required to avoid cracking also. When the hot forming operation was tried with the furnaces at 1,850° F., cracks showed in the surface of the sleeves.

An inside honing and an outside superfinishing completed the machining of the valve sleeves. Valve surfaces were finished to 15 rms. and placed in engines without any further conditioning. The finished valves were remarkably stable geometrically under rough usage and handling. One test which all valves successfully passed was that of bending them in a vice to approximately 50% of their original diameter without cracking and on the springback, they return to within 0·0005 in. of their original diameter.

The nitrided sleeves gave excellent performances in service. Tests made upon motors under controlled conditions gave the following results :—

	Wear
After 500-hr. running ..	less than 0·0005 in.
After 1000-hr. running ..	less than 0·0005 in.

Although specifications were close, the process gave very satisfactory results from an inspectional standpoint. During the entire run of several thousand production valves, only 2% of the pieces varied noticeably from the nominal dimensions. No pieces were rejected for hardness.

Cast Bolts for Pipe Joints

By C. K. Donoho

BOLTS used for assembling mechanical joints for pipe constitute a vital part of the pipe-line construction. The primary qualifications for such bolts are : (1) high yield strength, (2) toughness and ductility sufficient to withstand any ordinarily encountered shock or bending stresses, and (3) corrosion resistance equal to, or better than, the pipe with which they are used.

A method is described for the production of cast bolts having these desired qualifications. The development was made by the American Cast Iron Pipe Company (U.S. Patent No. 2,220,792), and resulting application, known as the Acipco standard cast-iron bolt, has been in continuous production since 1937. The principal application is in mechanical joints for cast-iron pipe lines conveying liquids and gases. Sizes cast range from $\frac{5}{8}$ to $1\frac{1}{2}$ in. diameter, and 3 to 7 in. lengths. The metal composition, method of casting and heat-treatment of these bolts constitute an interesting metallurgical process.

Melting Process

At present melting is carried out in a 24 in. diameter cupola, producing about 2 tons of molten iron per hour. The metal charge is composed essentially of steel, return scrap, and high-silicon pig iron. Iron-to-coke ratio is about 5–1. The molten metal flows continuously from the cupola breast into a mixing and desulphurizing ladle of capacity sufficient to hold 3 or 4 complete charges. From the mixer, iron is taken in 25-lb. hand ladles for casting. The desired average analysis in per cent. is as follows :

Total C	Si	Mn	P	S	Cu
2·50	3·00	0·85	0·12 max	0·15 max	1·25

Melting of iron as low as 2·50% carbon in the cupola is facilitated by the high silicon and copper contents which reduce the carbon solubility. The temperature of metal from the cupola is 1510°–1540° C, and casting temperature averages about 1344° C.

Casting

Bolt blanks are cast one at a time in split metal moulds mounted on a turntable carrying 60 moulds. The turntable makes one complete revolution every 2 to 3 minutes. At the pouring side of the turntable, the two-part moulds are held in the closed position by springs. At the opposite side pusher arms, acting on a cam at the centre of the wheel, separate the split moulds to allow removal of the solidified castings. The moulds are open at the top and are poured by hand, head up, the head height being controlled by the pourer. Bolts are cast and stripped on one turntable at the rate of about 25 per minute.

The moulds are machined from blocks of soft grey cast iron. Blocks are accurately faced, and the mould cavity which forms the bolt blank is milled. In operation, the mould cavities are coated with acetylene soot from a torch controlled automatically. This

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TABLE 1. CHEMICAL AND PHYSICAL TESTS OF STANDARD CAST-IRON BOLTS.

Time	Si	S	Mn	C	P	Cr	Cu	Bend $\frac{1}{16}$ in. deflection	Tensile strength, 1000 psi	Bhn
8	3·04	0·082	0·77	2·47	0·10	0·042	0·96	4·2	63·3	187
11	3·06	0·090	0·83	2·40	0·11	—	—	4·9	61·3	192
1	3·11	0·093	0·85	2·37	0·10	0·042	1·17	5·6	63·0	187
8	2·86	0·132	0·72	2·48	0·10	0·042	1·31	5·6	67·5	179
11	3·08	0·093	0·87	2·49	0·10	0·043	1·40	4·2	64·1	179
1	3·12	0·080	0·90	2·54	0·10	0·040	1·14	4·9	64·6	183
8	3·10	0·129	0·92	2·63	0·09	0·045	1·25	4·0	61·0	187
11	3·09	0·124	0·85	2·46	0·11	0·046	1·41	4·8	60·7	179
1	3·10	0·104	0·83	2·55	0·13	0·044	1·18	4·2	58·9	179
8	2·74	0·101	0·75	2·15	0·10	0·041	1·24	4·2	69·0	170
11	3·10	0·144	0·91	2·49	0·09	0·042	1·06	4·8	64·6	179
1	3·10	0·071	0·89	2·71	0·08	0·046	1·18	5·6	68·2	170
8	2·89	0·090	0·85	2·56	0·09	0·044	1·50	4·8	62·4	179
11	2·75	0·081	0·80	2·57	0·12	0·047	1·59	3·8	63·6	187
1	2·98	0·110	0·87	2·57	0·09	0·046	1·31	5·6	67·3	179
	3·00	0·100	0·84	2·52	0·10	0·044	1·26	4·7	63·9	181

soot coating protects the mould and produces a smooth-surfaced casting. A new mould will produce about 5,000 bolts before it must be reworked.

Heat-Treatment

The as-cast bolt blanks, of hard brittle, white iron, are placed on alloy trays and annealed in a continuous pusher-type annealing furnace. The time-temperature cycle each bolt undergoes is approximately as follows: Heat to 950° C, hold 1½ hour, air cool, re-heat to 840° C, cool to 676° C in 1½ hours, and air cool. This treatment decomposes substantially all the combined carbon to produce a true malleable structure, Fig. 4. The air cool from 676° C is used in order to retain most of the copper in solution; an important factor for best ductility and corrosion resistance. The annealed bolt blanks are then rattled, gauged, and threaded in production bolt-threading machines.

Nuts are cast in sand of soft gray iron, but with 2% of copper for corrosion resistance. These are annealed at 870° C to facilitate tapping. The nut iron has a tensile strength of only about 15·6 tons/sq. in., compared with about 30 tons/sq. in. for the malleableised bolt. Many tests have proved, however, that a high unit strength is not necessary for the nuts. Tightening the bolt and nut together in a joint to failure will almost invariably cause the bolt to break in tension before the nut fails.

Mechanical Properties

Hardness and strength values of the bolt metal so produced are considerably higher than those of ordinary malleable iron, because of the effect of the 3% of silicon and 1¼% of copper in solid solution.

Sample bolts for test are selected three times in each 8-hour heat. A typical test report for one week is shown in Table 1. The tensile test is made by pulling a threaded bolt to failure and calculating the results by dividing the ultimate load by the area at the root of the threads. The bend test results are expressed in sixteenths of an inch vertical deflection of a ¾ in. diameter bolt blank on a 6 in. span when loaded at the centre through a 1 in. diameter pin.

Corrosion Resistance

By reason of the copper content in solution in both bolts and nuts, the bolt-nut combinations are slightly but definitely cathodic to unalloyed iron or steel in a conducting environment. This is an important factor in corrosive services, because the electrochemical corrosion currents will run generally from pipe to bolts and not in the reverse direction, so that the bolts in effect are protected cathodically. In strong acids, corrosion occurs more by direct chemical action and here, too, the standard bolts and nuts are more corrosion-resistant than the plain iron with which they are used. Results of a typical test are shown in Table 2. In this test the unalloyed grey iron was sand cast in the shape of bolts and nuts in order to make the test as far as possible a true comparison of materials.

TABEL 2.—ACCELERATED CORROSION TEST OF STANDARD COPPER-ALLOYED BOLT IRON WITH PLAIN IRON.
(One week in 5% sulphuric acid; each specimen, one coupled bolt and nut).

Specimen No.	Part.	Loss in weight Grams	Per cent.	Grams sq./cm.
1	Standard bolt	10·6	3·4	0·13
	Standard nut	18·5	24·6	0·77
	Total	29·1	7·6	0·28
2	Standard bolt	12·6	4·2	0·16
	Plain iron nut	22·2	30·7	0·92
	Total	34·8	9·3	0·34
3	Plain iron bolt	71·0	22·2	0·89
	Standard nut	20·2	27·2	0·86
	Total	91·2	23·3	0·87
4	Plain iron bolt	61·9	21·9	0·77
	Plain iron nut	32·1	45·1	1·37
	Total	94·0	26·7	0·91
Average	Standard bolts	11·6	3·8	0·14
Average	Plain iron bolts	66·4	22·6	0·83
Average	Standard nuts	19·4	25·9	0·82
Average	Plain iron nuts	27·2	37·2	1·22

Another typical accelerated corrosion test was made by bolting two plain cast-iron bars (cast of normal pipe iron) together with four bolts and immersing in 2% sulphuric acid for four days. The losses in weight of bolts and nuts in contact with plain cast iron are given in Table 3.

TABLE 3.—TESTS ON PLAIN CAST-IRON BARS

Material	—Loss in weight, per cent.— Bolt	Nut
Steel	8·8	50·7
Pearlitic malleable ..	15·7	40·7
Standard bolt metal (1) ..	6·6	25·2
Standard bolt metal (2) ..	4·5	38·6

Austenitic Malleable Iron

A special development of the bolt process is the production of austenitic malleable bolts which are used for supercorrosive conditions or where a higher degree of toughness and ductility is desirable. The metal used is compositionally a modified Ni-Resist. The total carbon is kept low and the chromium on the high side.

Desired average analysis in per cent. is as follows:

Total C	Si	Mn	P
2·30	2·00	1·25	0·10 max
S	Ni	Cu	Cr
0·12 max	15·0	6·0	3·0

This metal is melted in the same 24-in. cupola used for the standard bolt iron and is cast in metal moulds on the same bolt turntable. Because of the chilling action of the metal moulds, this metal also casts white in sections up to 1¼ in. diameter. Annealing at about 980° C decomposes most of the combined carbon to produce a soft, tough, austenitic malleable iron. This metal has a tensile strength of about 30 tons/sq. in., as compared to about 14 tons/sq. in. for sand-cast Ni-Resist, and significantly higher ductility.

Acipco Ni-Resist bolts, especially when coupled with plain iron as in a pipe joint, possess corrosion resistance comparable to that of bronze or stainless steel in most services. Table 4 shows the results of an accelerated electrolytic corrosion test made on joint sections bolted with several types of bolts. This is a very severe type of test. With lower current, or no current, there is a much greater superiority of the last two materials in the table.

TABLE 4.—ELECTROLYTIC CORROSION TEST OF JOINTS OF 3-IN. CAST-IRON PIPE BOLTED WITH DIFFERENT BOLT MATERIALS.

Bolt material	—Loss in weight, per cent.— Bolts & nuts	Entire joint
Mild steel (black) ..	31·0	28·9
Cadmium-plated steel ..	22·7	28·1
Galvanised	16·1	26·4
Acipco Ni-Resist	3·5	27·4
18.8 Stainless steel ..	2·1	26·4

Electrolyte: 2% NaCl in water.
Current: 0·9 (average) from joint as anode to lead-lined tube as cathode.
Duration: 106 days.

STEELS IN GERMAN AIRCRAFT.

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Stress-Relief Hardening of Beryllium Copper

By Robert W. Carson

IN the 15 years since the material was first announced, the unusual properties of beryllium copper have led to a number of applications, many successful and some disappointing. Each successful application has required a design based upon the physical properties which are characteristic of the material, as well as knowledge of the effect of heat-treatment on these properties. In no design has the problem been solved merely by substituting beryllium copper for another material.

No other material combines so many properties so often helpful in design. Beryllium copper is not only as corrosion-resistant as brass and phosphor bronze, but also is nearly twice as strong. It is non-magnetic. It has endurance strength nearly equal to steel; higher under corrosive conditions. Its electrical conductivity is twice that of bronze and it will maintain spring properties under temperatures 100° F. higher than bronze. In addition, it has less tendency to drift or take a set than almost any other spring material. Since it is hardened by heat-treatment after forming, beryllium-copper parts can be made in forms and shapes impossible to duplicate in many other alloys.

One of the important factors behind the successful application of beryllium copper to a variety of products to-day is stress-relief-hardening or fixture heat-treating. Fixture hardening is a fairly common practice in some types of steel parts, such as gears and cam shafts, and has been used to a limited extent in special steel-spring applications, but the properties of beryllium copper offer a unique opportunity. By proper selection of heat-treating time and temperature beryllium copper can be thoroughly stress-relieved during hardening. Or expressing the idea another way, the age-hardening can be carried out at a temperature high enough for the elastic strength to become zero. Under such conditions the part "sets" to the shape in which it is held during hardening, and after cooling to room temperature its high elastic properties cause it to retain its shape.

Conformity to a fixture is controllable to a considerable degree by the hardening temperature, and under certain conditions some sacrifice in final elastic properties must be faced when maximum conformity is desired. The higher the hardening temperature, the better the conformity; but hardening heat-treatments above 725° to 750° F. usually does not develop full hardness and strength. So, the best heat-treatment is often a compromise.

One of the first, and to-day one of the largest, uses is the spring element in small snap-action electrical switches. The significance of beryllium copper here is that it made the industry possible. The utility of these switches rests on two major factors, i.e., small size, and freedom from failure. Beryllium copper made both available through its exceptionally high endurance strength. However, other factors also played a part. Uniformity in operation required close tolerances and accurately held shapes, as well as high electrical conductivity and resistance to heat, and the possibility of forming intricate shapes accurately in the soft material, depending upon heat-treatment to develop needed spring properties.

Other factors also were important; for example, fixture-hardening of the beryllium-copper parts reduced manufacturing costs by more than enough to cover the added material cost. With conventional spring materials for such parts, hand-adjusting had traditionally been accepted as unavoidable. By taking advantage of fixture hardening, each of these springs was made to the desired final shape and had sufficiently high strength to undergo handling and assembly operations without distortion.

In the case of a sensitive relay, the armature spring is formed from ¼ hard strip 0·008 in. thick in a one-operation progressive die. Springback in forming is variable and, even with the most careful handling, parts are liable to be bent out of shape. However, the parts are stacked in a steel fixture designed to hold the final desired shape and hardened while held in the fixture. In this relay spring still another factor had to be considered. Electrical conductivity was important, and it too required a higher heat-treating temperature than one giving maximum spring properties. Therefore this part was purposely overaged with a loss of 10% of its maximum proportional limit in order to obtain good conformity and higher conductivity.

On a direct cost comparison between similar springs made of phosphor bronze and fixture heat-treated beryllium copper, the lower-cost answer for this relay spring was beryllium copper. The piece price was substantially higher, but elimination of the hand adjusting operation required for the bronze part was more than the difference in piece cost. In addition, the manufacturer obtained better life, better conductivity, and higher safe operating temperature.

An electric-range switch uses four flat blades to which contacts are attached. Each blade is fixture heat-treated to eliminate hand adjusting operations formerly employed. As compared with bronze, the beryllium-copper blades with higher conductivity and heat resistance permit the use of thinner shorter blades, which reduces the size of the unit and improves its sensitivity. The net result is a more compact, more accurate control, manufactured at lower cost.

Another cost-reduction application for beryllium-copper coil springs is found in the adjustable pressure controller of the bellows-operated snap switch type, in which a small coil spring is used to provide snap action in the spring blade. For desired control of pressure differential, the force exerted by the spring at its compressed or working length had to be held within 2%. For coil springs produced on an ordinary coiling machine, springback in coiling affected coil diameter, free length, and number of turns, requiring in this application 100% testing and sorting after a careful stress-relieving heat-treatment. However, mandrel-coiled beryllium-copper springs are supplied to sufficiently close tolerance to eliminate all this extra labour with a substantial reduction in handling, inspection and reworking.

Several other examples are given and illustrated to show that making use of opportunities beryllium copper offers in such applications requires a fundamentally different approach to design. In all of the devices illustrated, substantial overall savings in cost were obtained even though the cost of the parts was much greater than for ordinary materials. In each case beryllium copper was the lowest-cost answer. In most cases there were other advantages obtained by proper design use of the higher physical properties of hardened beryllium copper. For more specific data on applying the technique used in fixture heat-treating beryllium copper, several references are cited.

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